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VI



A
GENERAL SYSTEM
OF
CHEMICAL KNOWLEDGE.

&c. &c.

A
GENERAL SYSTEM
OF
CHEMICAL KNOWLEDGE;
AND ITS
APPLICATION
TO THE
PHENOMENA OF NATURE AND ART.

BY **A. F. FOURCROY,**
Of the National Institute of France, Counsellor of State, Professor
of Chemistry at various Public Establishments, Member
of many Academies, &c.

IN ELEVEN VOLUMES.
TOGETHER WITH A SET OF SYNOPTIC TABLES, IN LARGE FOLIO.

TRANSLATED FROM THE ORIGINAL FRENCH,

BY **WILLIAM NICHOLSON.**

VOL. VI.

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SIXTH VOLUME.

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A
S Y S T E M
OF
CHEMICAL KNOWLEDGE.

CONTINUATION OF THE

SIXTH SECTION.

ARTICLE XVI.

Concerning Tin.

A. History.

1. **TIN** is one of the metals which was the earliest known, and of which, as it should appear, the discovery must have been among the first made by men; at least this discovery appears to be hidden in the darkness of ancient times, even beyond those of fabulous history. The Egyptians made great use of it in their arts; and the Greeks alloyed it with the other metals. Pliny, without composing an accurate history, or precisely comparing its qualities with those of the other metals, speaks of it as a metal

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B

well

well known, and much employed in the arts, and even applied to a great number of the ornaments of luxury. He often calls it white lead, and points out its frequent and fraudulent contamination with black lead, or lead properly so called. He attributes the invention of tinning to the Gauls. When we consider the easy treatment and fusion of tin, we should not have any reason to be surprised that its use has been so frequent among the earliest nations, if it existed in the native state, or if its ore were easy to be worked. But when, on the other hand, we reflect on the difficulty of exploring this metal, and the little resemblance of its ore to that of the metallic tin, we cannot easily conjecture how the discovery and use of tin should date in times so very remote.

2. The alchemists have attended greatly to tin: they named it Jupiter; and have distinguished its various preparations by the name of Jovial. By comparing it to this planet, they explained, according to Boerhaave, the hieroglyphic science by which it is represented. The left portion of this sign presented the character of the moon; and the crescent to which it was connected at the right, the cross, the sign of a crudeness of the reddening quality so frequently used to denote this property in the acids. By this sign they expressed the remarkable similitude of tin to silver; the relation which, according to them, was well known by all assayers, from its fixity in the cupel, and also

also the unknown and the pretended crude sulphur which they supposed was necessary to be removed, in order to transmute it into silver. This chimera has long tormented the spirit of the alchemists, and led them to try every method of operation upon this metal.

3. Tin has been examined by a great number of skilful chemists. Those who were busied in operations of art, relative to medical objects, have attempted to prepare it in a great variety of methods; less, numerous, however, than those which have been applied to iron, antimony, and mercury, for the purpose of appropriating them to various medical uses. La Poterie, or Poterius, distinguished himself in this class, and has given his name to a medical preparation of tin, distinguished by the denomination of *antihædic*. It is, however, a metal in which pharmacological chemists have placed the least confidence; most of them have been apprehensive of an arsenical admixture, which they apprehended it to contain. Margraff has given authority to this idea, and increased the suspicion by his analysis of this metal, in which he affirmed that he had found a very alarming proportion of arsenic. Schultz nevertheless announced that pure tin is in no respect dangerous: and the valuable labour of Bayer on this subject, has dissipated all obscurities, and destroyed every apprehension which the wonderfully erroneous results of Margraff had thrown over its economical use.

4. The systematical authors of chemistry, particularly those who have described processes from Lemery and Rouelle, have greatly extended our knowledge of this metal. They have successively treated it with the principal acids, the salts and the alkalis; they have studied its alloys, and its different combinations; and we are particularly indebted to Macquer and Baumé, for the greatest number of experiments on this object. The mineralogists, and metallurgists, have also carefully studied this metal, and its different states in nature, as well as the processes for assaying and working its ores.

5. I am not acquainted with any author who has expressly undertaken to make a complete history of tin. The extensive articles of Baumé, of Macquer, of Wäasserberg, and Gren, do, indeed, present us with a collection of the principal facts which they possessed at the period of the publication of their works respecting tin; but this metal has not yet had any particular historian, like antimony, mercury, iron, silver, gold and platina: nevertheless, its remarkable properties, and important uses, entitled it, in some respect, to this honour. Indeed there are many particular memoirs respecting some of its combinations. Libavius first discovered a singular product of the decomposition of the super-oxygenated muriate of mercury by tin, and gave his name to that product. Bergman has treated upon the sulphureous ore of tin, or native species of aurum musicum, from Siberia.

Bullion

Bullion and Pelletier have given well-written dissertations on the preparation of phosphorated oxide of tin, Rouelle the younger has published useful experiments on the decomposition of the super-oxygenated muriate of mercury by tin. Bayen and Charlard have enriched chemistry with a series of valuable researches on the analysis of the alloys of this metal, and the art of ascertaining its purity, or the metallic substances which change it.

6. Since the revolution of chemistry, without its having become the object of a connected series of experiments, in all the details of its properties, according to the ingenious method which this revolution afforded to our experimental art, tin has been the subject of a number of capital discoveries, some of which have concurred to establish the pneumatic doctrine, and others have served to give firmness to its basis, and establish its results. As it was to this metal that John Ray directed the attention of philosophers in 1630, by his opinion, that air is fixed in the metal during its calcination; and as Boyle, at the end of the same century, endeavoured to ascertain the cause of the augmentation of weight in its calx, so Lavoisier repeated and rectified in 1774, the experiment of Boyle, by calcining tin in a large closed vessel of glass, containing a certain known quantity of air. By this experiment he opened, in a certain degree, the scene of his astonishing chemical researches upon air, and proved

proved that the pretended calcination of metals is merely a combination, in which a part of atmospheric air becomes fixed, and combines with them. Since these interesting experiments, Citizens Adet and Pelletier, by ingenious methods examined the muriate of tin in its two states, and have shown how much the properties of this metal may be cleared up by the pneumatic doctrine, and how greatly these properties are themselves calculated to establish the principal points of that doctrine; accordingly, though the researches of chemists upon tin, are far from being exhausted, we shall, nevertheless, find, that the history of this metal, presented according to the exact data of the pneumatic chemistry, offers precise and exact results, and a much more perfect whole, than could be formed in the systematical works written before, or even since that happy epocha.

B. Physical Properties.

7. PURE tin is of a white colour, equal in beauty and brilliancy to that of silver; and if this colour were not changeable, it would, with regard to this property, be as valuable as silver. It was formerly considered as the lightest of metals, when a distinct and particular class was made of the semi-metals. Its specific gravity is from 7,291 to 7,500, according to the comparative experiments of philosophers, from

Muschenbroeck to Brisson, upon different suppositions. It occupies the twelfth rank with regard to this property.

8. It is one of the softest of metals. It may be easily scratched with the nail; and there is scarcely any other metal which cannot injure its surface by pressure or by friction. A knife readily cuts it: it may be easily bended, and when bended affords a peculiar crackling noise. In this property it has been compared to zinc, but the noise is very different, or much weaker in zinc than in tin.

This phenomenon appears to depend on a separation of its parts, and the sudden fracture which they suffer by the bending, though tin is not easily broken. Its sonorous quality is feeble; its ductility is sufficient to admit of its being reduced by the hammer, or laminating cylinder, into very thin leaves, which are of great use in the arts. It holds the fifth rank among the metals, in this property. It has little elasticity or tenacity; a wire of this metal, of $\frac{1}{16}$ of an inch diameter, supports, without breaking, a weight of $49\frac{1}{2}$ pounds French.

9. Tin is one of the most dilatable of metals by caloric, according to the pyrometric experiments of Muschenbroeck. A small cylinder of this metal, six inches long, exposed to heat, in boiling water, afford a dilatation equal to .64. This philosopher places tin in the first order of dilatable metals, and iron in the last; whence it should seem, that the dilatability of metals may follow

follow the ratio of their fusibility. Its conducting property of caloric, is also very striking. After mercury, tin is the most fusible metallic substance; it comes immediately before bismuth and lead in this respect. Citizen Guyton expresses it by the 168th degree of Reaumur's scale. When fused, it does not rise in vapour but at a very elevated temperature; it has ever been considered as one of the most fixed of metals, on which account the alchemists thought it considerably resembled silver. If it be suffered to cool slowly, and when its surface is congealed it be pierced, and the part which is still fluid be carefully poured out, the interior presents crystals in rhombs of considerable size, formed by the assemblage of a great number of small needles longitudinally united. One of my pupils, Citizen Hapel-Lacheneye, who is at this time at Guadaloupe, where he has been for several years employed in valuable researches upon the colonial productions, was the first who crystallized tin in this manner, in my laboratory, in the year 1782.

10. Tin is a very good conductor of electricity, and is frequently used for this purpose for covering conductors, and for Leyden bottles. It is also effectual with regard to animal, or galvanic electricity, which it strongly conducts when it is in contact with a nerve, and has communication with another metal.* It has a very remarkable odour, with which it impregnates the hands and bodies rubbed with it. Its
taste

taste is also very sensible, and there is no doubt but that it possesses very powerful medical properties, as I shall show by experiments at the end of this article.

C. *Natural History.*

11. TIN is not very abundant in the bowels of the earth, at least in Europe. Very few mines of tin are known in Asia and Africa. There are some in Siberia; but they are more frequent, and more rich, in Cornwall, in Bohemia, and in Saxony. The most skilful mineralogists have hitherto distinguished only three species of tin ores, namely, native tin, its oxide, and its sulphurated oxide.

12. Native tin has been an object of doubt and discussion in mineralogy. It is said to have been found in Saxony, Bohemia, and in Malacca. Some naturalists have denied its existence; but Mr. Woulfe, an English chemist, has terminated this scientific dispute by the discovery of native tin in Cornwall, in the year 1766. This tin is grey and brilliant in its fracture; it flattens, and affords brilliant and ductile plates under the hammer. It is found in thin plates, engaged in a gangue of quartz, or regularly crystallized. Mr. Quist has confirmed the nature of this mineral by his experiments. It was thought to have been found in France a few years ago near the commune of Espieux,

in

in the department of La Manche. Citizen Schreiber, inspector of the mines, being sent to the spot by the council of mines, carefully examined the specimens and the places whence they were obtained, and has decided that they were only accidental. Those pieces were cracked, and covered with a grey oxide, in which was seen metallic tin, ductile, adhering to a white substance, lamellated, crystallized, and which was known to be muriate of tin. They were simply deposited in a particular place, without any other trace of tin ores, so disposed and isolated as to lead to the conclusion that they were neither in appearance nor properties a native production; and every thing tends to show that they arose from an ancient tin manufactory which had been buried in the ground.

18. The native oxide of tin is the most frequent ore of this metal, and at the same time most variegated. However numerous these variations may be, they must all be arranged under one and the same species. They are in general denominated crystal, or crystals of tin. The primitive form of these crystals, according to Citizen Haüy, is that of a cube performing the function of a parallelopipedon, of which the dimensions are different on the opposite faces from what they are on the four other faces; these then represent the sides of a prism. These crystals exhibit a concave angle, formed of four triangular faces, arising from the junction of two portions of the same crystal, one of which is applied

plied against the other in a reversed situation. This has been denominated by Citizen Haüy, hemitrope oxidized tin, or half turned. There is another variety of form, which he calls distic oxide of tin, or with two ranges of facets, having thirty-six faces, of which four are vertical. The grey, light yellow, white, yellowish, red, brown, and black colours, form so many varieties of native oxide of tin, which mineralogists have distinguished and described in some places as species. The native tungstate of lime, in the octahedral form, has been often, and for a long time, confounded with the white oxide of tin; but besides the octahedral form, which this last has not, the tungstate assumes, as has been often remarked, a citron yellow colour, by the action of the nitric and muriatic acids, which the oxide of tin does not. The specific gravity of these oxides of tin amounts to between 5,955 and 6,750. Mr. Kirwan distinguishes four varieties of this species, to wit:

a. The oxide called white tin ore, or tin spar; it is semi-transparent, crystallized, whitish, inclining to grey, greenish, or yellowish, containing no arsenic, as has been thought, and was long ago found by Margraff to be the purest of tin ores. Its specific gravity is 6,007.

b. The brown or black opaque oxide, the commonest of these ores, often crystallized, contained in quartz, mica, or fluato of lime, never in calcareous carbonate, called zingraupen, when in large crystals, by the Germans, and when in small crystals

tals zinzwitter; containing near 0,80 of tin always united to iron, and of the specific gravity of 6,750. Mr. Klaproth has analyzed this variety from Alterna in Cornwall, and found the following proportions :

Tin	-	-	-	77,50
Oxygen	-	-	-	21,50
Silex	-	-	-	0,75
Iron	-	-	-	0,25

c. The reddish, or reddish yellow oxide of tin, called garnet tin ore by naturalists; it is in small crystals, sometimes semi-transparent, or in a striated spherical form, resembling the hematite or zeolite; it weighs from 5,300 to 5,800. It contains more oxide of iron than of tin.

d. Sandy tin, or tin-stone, or zingstein of the Germans, and tinberg of the Swedes. It is the oxide of tin, of all the preceding colours disseminated in a quartzose, or sandy earth, more or less friable.

14. The sulphurated oxide of tin, or tin mineralized by sulphur of the mineralogists, has been discovered and described for the first time by Bergman, among the minerals of Siberia. He found two varieties, one of the colour of zinc, of a fibrous texture, containing 0,20 of sulphur, and 0,80 of tin; the other enveloping the former like a yellow incrustation, or very similar to what chemists denominated aurum mufivum, containing 0,40 of sulphur, a little copper, and the rest tin. Since this discovery Mr. Klaproth has examined the sulphurated tin from

from the parish of St. Agnes, in Cornwall. Its specific gravity is 4,350; its colour shaded of a pale and deep grey, resembles that of silver in its purest parts. Its fracture is granulated and metallic. He found the following proportions:

Sulphur	-	-	0,25
Tin	-	-	0,34
Copper	-	-	0,36
Iron	-	-	0,02

The copper in this appears to be more abundant than the tin, but its quantity, which varies, is frequently less than that of the tin.

D. Assays and Metallurgy.

15. THE assay of tin ores was formerly made by roasting and reduction with flux, and in no other method; the roasting which many assayers thought necessary for volatilizing the arsenic, is of no other use than to attenuate and divide the ores, which are usually very hard, and very dense. It was made in a covered capsule, in order to prevent the dissipation of the tin. Some have advised to mix a little pitch, in order to prevent the tin from being too much oxidized. The roasted ore was fused very hastily with three times its weight of black flux, and a little decrepitated muriate of soda. The comparative weight of the ore before the roasting, and afterwards, as well as that of the metallic button obtained, and of the scoria which covers it, exhibit

hibit the quantity of metal to be expected from the ore.

16. Cramer, one of the most celebrated authors upon assaying, gives another process, which is more expeditious, and subject to less of loss in the assay of the ores of tin. He chooses two large pieces of charcoal of linden, or hazel, very uniform, without excavations or cracks. In one of these he makes a cavity, intended to answer the purpose of a crucible, in which he puts simply the pulverized tin ore, mixed with a little pitch. He perforates the other with a small hole, intended to give vent to the oily vapours; he applies this upon the former as a covering, and ties them together with iron wire, after having luted the places of junction. This apparatus is placed, with the support of the other pieces of charcoal opposite the nose of a forge bellows, and speedily lighted. After a few minutes strong blast, the charcoal is extinguished by plunging it in water, and the tin is found in the form of a button in the excavation.

17. Another method has also been proposed to make the same assay. After pounding and washing the ore thus separated from the quartzose portions, which are frequently more abundant and lighter than the parts of the oxide of tin, these last are to be speedily fused in a lined crucible, well covered, having previously mixed them with twice their weight of a flux, composed of equal parts of pitch and calcined borax. Bergman,

man, in his edition of Scheffer, advises to mix one part of washed ore with two parts of tartar, one of black flux, and half a part of pitch; to separate this mixture into three equal parts, and to project them one after the other into a crucible, at a white heat, which is to be covered up as soon as each portion has ceased to burn. The operation performed in this manner lasts only, according to his report, from seven to five minutes. Mr. Klaproth, having remarked that the alkalis occasion a loss by dissolving a part of the oxide, has succeeded by a more simple process. It consists in placing the ore in powder, in a charcoal crucible, included in a lined crucible of clay, which he exposes to the heat of a forge for half an hour.

18. With regard to the humid assay of tin ore, the following are the instructions of Bergman: Native tin is very easy to be examined; the nitric acid speedily oxidizing it, reduces it to white powder; and if it contain iron or copper, these two metals remain in solution: an hundred parts of tin afford an hundred and forty parts of white oxide, by this acid, after the same has been washed and dried. The native ore in the form of oxide, mixed with quartz, is very hard, and is attacked by no single acid, on account of the great oxidation of the tin in its mixture with flux. Bergman has, nevertheless, succeeded in analyzing it, by the following process: he pours upon the levigated ore, concentrated sulphuric acid, and digests by a strong heat for several hours; after which

which he adds to the cold mixture a little muriatic acid with agitation, by means of which a strong heat, and lively effervescence are produced, in consequence of a portion of muriatic acid being deprived of its water, and reduced into gas by the sulphuric acid; the force of these two acids united, effects that solution which separately neither of them were capable of; an hour after this addition of muriatic acid, Bergman poured water on the mixture, which he suffered to settle, and decanted the supernatant fluid, which held the oxide of tin in solution. The same operation repeated till these acids can take up nothing more from the ore, afforded him on the one hand the whole of the oxide dissolved, and on the other, the quartzose part insoluble. He precipitated the oxide by the carbonate of soda, and found that 181 parts of this precipitate represent 100 parts of metallic tin. If this oxide contains iron or copper, if it be heated for some time with contact of air, and successively treated by the nitric and muriatic acids, the first dissolves the iron, and the second the copper, without touching the oxide of tin. This last process was proposed by Kirwan, and it must, in fact, answer the purpose intended to be produced, by a more exact knowledge of the ores of tin.

19. Mr. Klaproth, in his analysis of the ores of tin, having observed that the whole of the oxide of this metal cannot be dissolved by the process of Bergman, and supposing that this
might

might be owing to its high state of oxidation, had recourse to that substance which in his hands, for several years past, has become so excellent and powerful a means of analysis. He fused one part of the ore of tin with six parts of caustic potash, in a silver crucible, keeping the mixture ignited for half an hour. He diluted this matter in water, which dissolved it without acquiring any colour; he poured in muriatic acid, which formed a white precipitate, again soluble by excess of the acid; after which he precipitated the oxide of tin by the carbonate of soda. After having re-dissolved it a second time by the muriatic acid, he separated the tin by immersion of a plate of zinc. This process, in fact, succeeds much better than that of Bergman, because it is founded on the great solubility of the oxide of tin in the fixed alkalis.

20. The operation in the large way upon tin ores, considerably resembles the assays in the dry way which have been described. It is asserted, that in working these mines it is frequently necessary to burn fires, for the purpose of obtaining the gangue, and that these fires in the mine develop very dangerous vapours. All books speak of the arsenic disengaged from tin ores when roasted, and it is difficult to reconcile those assertions with the exact analysis, which does not show arsenic in the native oxides; at least, unless we suppose it to exist in the different minerals which accompany those native

Vol. VI. C oxides,

oxides, and contain, as it should appear, much arsenical matter. The ores of tin are sometimes found at little depths beneath the sand, as is seen at Eibenstock. This mine is so valuable as to be washed upon tables faced with cloth, for the purpose of retaining the metallic particles. These are roasted in reverberatory furnaces, and give out, according to various metallurgical authors, arsenic; in the form of an oxide, which is volatilized in horizontal chimneys; it is evident that this operation relates only to the arsenical mixture I have spoken of. The ore thus roasted, is afterwards fused in the furnace, and the tin is poured out into ingot moulds, where it acquires the form of blocks, under which it is sold.

Extensive tin works are carried on in England, in Germany, and in India. The purest of all tin in the market is that which comes from Banca and Malacca. This, which in most books is described as the purest, is in fact so, for it contains no foreign metallic substance. It has the form of a short, truncated, quadrangular pyramid, with a thin projecting edge, and weighing about one pound each piece. The tin of Banca, which is also very pure, is sold in ingots of forty-five or fifty pounds. Both are extremely grey, and covered with a thick rust, produced, no doubt, by the damp and salt air of the sea, and the vapours with which they have been surrounded on ship-board. The English tin, which is more used than that of India,

India, is fold in large pigs of about three hundred weight each. It is alloyed with copper, either naturally or artificially; for the laws of England ordain, that it shall not be exported without this alloy*. Accordingly that kind of tin which has the form of grains, or stalactites, and is brought from England, was found to contain copper, according to the experiments of Bayen and Charlard. The tin of Germany and Saxony is no less impure; but it is not true that it contains arsenic, as Margraff asserted. We shall soon see that the quantity which he admitted, could not in any degree exist, without changing all its properties, and without rendering it incapable of answering uses to which it is destined. For the facility of sale the tin-workers cast it into small ingots or bars, of five decimetres in length, and from four to six centimetres in thickness.

E. Oxidability by the Air.

21. TIN is not oxidized in the air without heat, but very difficultly, but it soon loses its bright and beautiful white colour. When cut it is as brilliant and as clear as silver, but in a few hours this fine colour changes, becomes

* The ingenious author is mistaken with regard to the operation of a law of this kind: the impurity he speaks of must arise from other causes.

dull, and in a few days becomes tarnished. Long exposure to the air considerably increases this alteration, though it takes place only at the surface; so that at last it becomes of a dirty grey, without any brilliancy, and is covered with a light stratum of grey oxide. It is, therefore, necessary that vessels of tin should be frequently cleaned and brightened to renew their surface, and retain their beauty. But this weak oxidation never penetrates so deeply as to justify the assertion that tin, like the other metals, rusts in the air.

22. When tin is fused with the contact of the air, the metal when scarcely liquefied, becomes covered with a dull, grey pellicle, which becomes wrinkled, and separates from the portion of fused tin. When this pellicle is detached, another is formed, and by proceeding in the same manner, the whole of the tin may be converted into pellicles. In this oxidation the tin becomes brittle, and of an earthy appearance, and this oxide formed at its surface can no longer adhere or combine with the metallic portion. In the art of casting and purifying tin vessels, this oxidized matter, formed at the surface of the metal in fusion, was called dross, and it is very evident that it is in the power of the founder to convert all the tin into dross; he consequently did not lose this pretended impurity, but knew very well how to recover it again in its metallic form, by heating it with tallow or resin. This crust is, therefore, a true grey oxide of tin; the
metal

metal contains from eight to ten per cent. of oxygen, and it is very easily reduced. If tin be continually heated with the contact of air, particularly with agitation, it becomes divided, attenuated, and is changed into a powder, which gradually becomes white, with increase of weight, is more oxidized, and constitutes what is called putty of tin in the arts. This last oxide contains, according to the comparative experiments of J. Rey, Van Helmont, Boyle, and Wallerius, between seventeen and twenty parts of oxygen, with one hundred of the metal. Lavoisier, in making this experiment in a glass retort, hermetically closed, obtained a blackish oxide in light flakes, and has proved, that its augmentation of weight is exactly proportional to the loss which the air in the apparatus has undergone.

23. The oxidation which I have here described, is only the first and weakest combustion of the tin; it is capable of undergoing a much stronger combustion when its temperature is greatly raised: and when it is urged after its fusion to a red heat, sufficient to reduce it into vapour, it then presents a true inflammation. If it be thus heated in a small quantity, upon charcoal, by the flame of the blow-pipe, and if the globule, the moment it begins to ignite, be thrown out of its receptacle, so that it shall fall on the ground, the tin is dispersed in luminous globules truly inflamed, which move, and are

agitated, for some time, upon the pavement, throwing out burning sparkles, which exhibit a very agreeable spectacle. The same effect is obtained, according to an old observation of Geoffroy, when tin is strongly heated in a crucible. When this vessel is of a strong red heat, the metal already covered with a stratum of oxide, rises, and starts out in jets, which exhibit, in the air, a lively white flame, similar to that of zinc. We also see, that these jets of flame are succeeded by fumes of a white oxide, which is condensed, upon cold bodies, in brilliant and transparent crystalline needles.

24. The exposure of tin to a strong heat, for a varied space of time, with constant access of air, and the remarkable phenomena which accompany its oxidation, have been the subject of important experiments made by Margraff, Macquer, Citizens Darcet and Baumé. These four chemists agree in remarking, that the oxide of tin formed in this case, is partly crystallized in fine needled prisms of the most beautiful white; that this oxide rises, and forms herbizations or vegetations, imitating a cauliflower; that under this snow-white substance is found another reddish oxide or glass, of an hyacinth, or violet colour, or ruby, or garnet-red, which immediately covers the unaltered portion of metal, where the contact of the air has been prevented, and consequently no oxygen absorbed. In some of the experiments a pure yellow glass
was

was afforded, or green vitrified covering; but it is probable that this arose from iron, copper, or some other colouring metallic substance.

25. These grey, white, violet, or dark reddish colours, assumed by the oxide of tin, in passing from the minimum to the maximum of its oxidation, by different degrees of vitrification, though less rich and shaded than those of many other metallic substances, show, nevertheless, that the various proportions of oxygen occasion corresponding changes in the state of its combinations, and appear to explain, by the greater or less degree of oxidation, the several modifications of the native oxides of this metal, from the white and the grey to the violet and the brown or deep red. They also explain the diversity which is met with in the putties of tin, in which we find shades of grey, white, yellow, and red; which appear to depend on the different proportions of oxygen, though they also may arise from the mixture of some other metallic oxides, particularly lead, copper, or iron.

26. While chemists have shown by these experiments, the tendency of tin to vitrify by an elevated temperature, they have not shown the means of determining the exact proportion of oxygen contained in the oxide at different degrees of oxidation. All that can be concluded, in general, from their remarks is, that the proportion of this principle, fixed in tin, never exceeds

exceeds eighteen parts in the hundred of this metal; so that it does not form quite the sixth part of the most complete oxide. They have also shown that this oxide of tin, as strongly burned as was last mentioned, becomes almost irreducible, or that it can scarcely be again restored to its metallic form, a circumstance which proves the great adhesion of tin and oxygen, an adhesion which many facts also prove, on examining the other properties of this metal.

F. Union with Combustibles.

27. **THERE** is no known combination between azote, hydrogen, carbon, and tin. Margraff has only observed, that when tin, in filings, is mixed with charcoal in powder, in equal parts, this mixture introduced, and very strongly heated in an earthen retort, afforded no sublimate or flowers, and a small proportion of that oxide of tin which he had obtained in his experiments upon the metal by itself; and that he likewise observed no fusion, but that it was merely changed into a coarse blackish powder. When the mixture was afterwards washed, he found the tin in very fine grains. Thus, in this assay the fusion of the tin in one single mass, had been prevented by the presence of the charcoal; and as there was no arsenical sublimate, we may be surprized that Margraff was not by this result prevented

prevented from admitting the existence of that poisonous metal in tin, particularly in the proportion he has asserted of its existence.

28. Phosphorus combines easily and strongly with tin, as has been shown in the valuable experiments of Pelletier on this combination. When phosphorus is thrown upon melted tin in a crucible, these two bodies unite, and the result is a phosphoret of tin, which contains 0,15, or 0,20, of phosphorus. This compound is of a silver-white colour; may be cut with a knife; crystallizes by cooling; has a lamellated texture; can be flattened under the hammer, but soon separates into plates: under the file it affords filings similar to those of lead; when thrown upon ignited charcoal the filings burn, and emit the smell and flame of phosphorus. Before the blow-pipe the phosphorus also burns, and the small button which remains is covered with a transparent glass. Margraff, who had obtained this phosphoret of tin without suspecting it, by a process which I shall hereafter describe, spoke of it as foliated and brilliant, brittle, resembling zinc, and affording a phosphoric flame upon ignited charcoal. Pelletier distilled this phosphoret of tin with the super-oxygenated muriate of mercury; and his products were the fuming muriate of tin, running mercury, and a phosphorated hydrogen gas, which took fire with detonation, on quitting the retort. There remained in the vessel an inflated matter, which burned upon charcoal in the

the manner of phosphorus, and which he conceived to be a combination of tin and phosphorus.

29. Sulphur easily unites with tin, and forms a compound, which exists in little abundance, as it should seem, in nature. Tin is combined with sulphur by throwing the latter upon the fused metal in a crucible: it is observable that the fusion of the tin is stopped. From this union, which absorbs sixteen or twenty parts of sulphur for an hundred of tin, there results a brilliant matter of a metallic grey, often bluish, of a lamellated and radiated fracture, crystallizing in cubes, which pass to the octahedron, attacked by the acids with effervescence, and very seldom found among the ores of tin, though art has so easily formed it.

30. If equal parts of oxide of tin, sufficiently oxidized, and of sulphur, be moderately and gradually heated in a retort or crucible, there is a disengagement of sulphureous acid gas, and sulphur, and there remains in the vessel a brilliant compound of the colour of gold, not volatile, crystallizable in hexahedral plates, not attacked by the acids, emitting sulphureous acid and sulphur, by a strong heat, and leaving a black mass of sulphuret of tin. This compound, which was described by Kunckel, and originally discovered by the alchemists, to whom it afforded chimerical hopes, has obtained the name of aurum musivum, musicum, mosaicum. It is the sulphurated, or hydro-sulphurated oxide of tin,

tin, of which the nature, the preparation, and the properties, were so well described by Pelletier in 1792, that scarcely any thing remains to be added to his complete examination of this compound. It is not, however, by the immediate process of heating the oxide of tin and sulphur, that this hidro-sulphureted oxide is prepared. We shall see hereafter the numerous list of very various means employed in its formation. It is sufficient that in general we observe, that whenever the oxide of tin is in contact with sulphur in a very divided state, or with hidro-sulphurets, at a certain degree of temperature, this golden compound is formed, respecting which I shall hereafter treat.

31. Tin does not easily unite with sulphurated hydrogen gas; nevertheless, when it is plunged into this gas, or in water, which holds it in solution, it speedily changes colour, assumes a golden yellow colour, and appears to decompose the hidro-sulphuret. This action is much stronger on the part of the oxides: these immediately become yellow, and afterwards black, when dried in the air, and assume the metallic and golden brilliancy of aurum musivum, when gently heated. The hidro-sulphurets and hidro-sulphurated water, speedily lose their odour in consequence of this alteration. It is very evident, that hidro-sulphurated oxide of tin, is in this case formed.

32. Tin is capable of combining with many metallic substances, and forms alloys more or less

less remarkable, but less with most of the metals already treated, than with those which remain to be treated of hereafter. Arsenic cannot be united by fusion in crucibles with tin but with great difficulty on account of its volatility. Margraff has shown, nevertheless, that this alloy may be made by means of the arsenious acid from which part of the tin takes its oxygen: and from this experiment it was, that he spread the alarm respecting the economical uses of tin. Citizen Baumé, by heating the acidulous arseniate of pot-ash, or Macquer's neutral arsenical salt, with tin, which this metal decomposes according to him, affirms that he obtained a brilliant, brittle and plated button, resembling antimony. Bayen has seen and described this combination much more accurately. He proved, in the first place, that the arsenious acid does not combine with tin; his experiments have shown, that the fears which have arisen in consequence of the erroneous experiments of Margraff, were merely chimerical. By treating fifteen parts of tin in filings, and one part of metallic arsenic in powder, in a retort, by ignition, he scarcely sublimed one seventieth part of arsenic in arsenious acid; this volatile metal became fixed by its combination with tin. At the bottom of the retort, a metallic button, exceeding the sum total of the two metals employed, was found, which was crystallized in large faces, or facets, like bismuth, but more brittle than zinc, more difficult to fuse than tin, and when softened by the fire, and

and pressed with a rod of iron, produced a noise by the friction of its plates, and from which the arsenic does not separate but by heating for a long time in the air. The examination which he made of this alloy of one sixteenth of arsenic, of which he carefully varied the proportions by adding tin; the means he has given to ascertain the presence of arsenic in tin, particularly by the muriatic acid, which dissolves the latter, and suffers the other to fall down in a black powder; the comparative analysis which he has made of all the wrought or crude tins used in France, have entirely assured the French government, and all reasonable men, that there is no foundation in the pretended danger of tin in domestic use. It results, in general, from his experiments upon arsenicated tin, 1. That the quantity of arsenic which Margraff supposed he had found in the tin of Morlaix, which amounted to almost a ninth of its weight, would be much more than sufficient to take away from that metal its well-known softness and flexibility, and to render it at least as brittle as zinc; 2. That the tins of Banca and Malacca do not contain an atom of this dangerous metal; 3. That the English tin, in large blocks, affords, by the action of muriatic acid, a small quantity of blackish powder, frequently mixed with copper and arsenic, in which the latter never exceeds a seven hundredth part, and is frequently less; 4. That the mixture made by the pewterers, of the tin of Malacca and Banca, with that
from

from England, diminishes still more this trifling proportion: 5. That arsenic united to tin, particularly when in so small a quantity as that which he has occasionally found, loses the greatest part of its corrosive and poisonous action; 6. Lastly, that the very small quantity of tin so weakly arsenicated, which can enter into our food by the daily use of utensils made with this metal, can have no influence upon the animal economy; since, according to the computation made from the loss undergone by a plate continually used for two years, the greatest quantity which can be taken, amounts to three grains per month: and, consequently, a 5,700th part of a grain of arsenic per day, supposing the tin wrought at Paris contains as much of that poisonous metal as the pewter plate from London, upon which Bayen made his experiment, which was already known to be false, before this simple and encouraging computation had been made.

33. The possibility of alloys of tin with tungsten, molybdena, chrome, titanium, uranium, and manganese, is yet unknown, and consequently their properties. It has merely been pointed out or shown, that it is capable of forming an union with cobalt, nickel, bismuth, antimony, mercury, and zinc. Tin and cobalt afford by fusion a metal in small close grains, and of a colour slightly violet. Cronstedt found that nickel alloyed with tin formed a white, brilliant, brittle, hard metallic mass, the specific character of which consisted more particularly

in the kind of vegetation, or swelling up, which it presented when heated under the muffle.

34. Tin alloyed with bismuth affords, according to Gellert, a brittle alloy, which is hard, and of a square, plated texture. The pewterers very often alloy this metal with bismuth, to give it whiteness and hardness. These two metals were long thought to resemble each other, inasmuch that the latter was called tin glass. Bismuth communicates a great stiffness to tin, and as it is a dearer article, the pewterers cannot employ more than an hundredth and half or two hundredth parts. This alloy is very easily shown, and separated with great accuracy by muriatic acid, which dissolves tin, but leaves the bismuth in the form of black powder, if the acid be sufficiently diluted.

35. Gellert, who has given the history of a great number of alloys, in his metallurgic chemistry, announces, that tin united with antimony forms a white, very brittle metal, the specific gravity of which is less than that of the two metallic substances separately taken. Antimony adds considerable hardness to tin, and changes its form and texture. This combination is employed in several arts, and particularly for plates to engrave music.

36. Mercury unites easily with tin, and in every proportion; we may affirm that it completely dissolves it, because the tin loses its solidity, and totally disappears, in a great quantity of mercury. Though this union may be effected in the cold, it is greatly favoured by heat.

heat. For this purpose the mercury is heated and poured into the tin in fusion. The amalgam which results differs in its solidity according to the relative doses of the two metals used. A solid amalgam of tin was formerly fabricated and cast into balls, with four parts of tin, and one of mercury. These balls were suspended in water, with the intention of purifying it, but as the water was boiled in this process, the purification probably arose from this last operation, which is capable of separating by precipitation the salts of sparing solubility, which impure and crude water usually contains. The amalgam of tin is capable of affording cubic crystals, which Daubenton first observed and described under the stoppers of glass bottles, in the collection of the museum of natural history, because it was formerly usual to close these bottles with solid amalgam of tin. Citizen Sage, who has made a series of experiments upon amalgams, affirms that the amalgam of tin affords grey, brilliant crystals, in leafy plates, with thin borders or edges, leaving polygonal cavities between them.

37. Zinc unites very well with tin, by fusion, and produces a hard metal, of a fine close grain, of which the ductility is greater the more tin it contains. It has long been observed that zinc produces nearly the same effect upon tin as bismuth, and the pewterers are aware that it may be substituted to this last; nevertheless it gives perceptibly less hardness than bismuth, and requires to be used in a greater proportion. But on the other hand, though it is not so effectual

effectual in augmenting its hardness, it diminishes its ductility very little, or rather it preserves it; whence this alloy is used in several of the arts. We are also aware that some chemists have observed several analogies between zinc and tin; but by rectifying the grounds of this comparison, we must also add that there are a much greater number of differences than of points of resemblance between the two metals.

G. Action upon Water, and upon the Oxides.

38. TIN does not act in any perceptible manner upon water alone in the cold, though I have already shown that it is one of the metallic substances which most strongly attracts oxygen. In fact, we have not yet a sufficient number of accurate experiments to deny this action totally, and there are a considerable number of chemical circumstances, in which, by the addition of a third body, tin truly effects the decomposition of water, absorbing its oxygen, and disengaging its hydrogen. Its oxide is not soluble, and contracts no union with water.

39. This metal is one of those which act in the most decided and speedy manner upon most of the oxides, from which it takes their oxygen. When heated, after having mixed its filings with those oxides, it causes them to pass to the state of metal, or very near it, while itself assumes the character of an oxide. Sometimes even, as

happens with the oxide of mercury, it burns and takes fire with activity, by absorbing the oxygen in a more solid state than it was in the other metal. By this strong attraction for oxygen it is, that tin has the property of precipitating a great number of metals from their solution in the acids. By this property the sulphuret of tin, heated with the red oxide of mercury, affords running mercury, and a small quantity of aurum musivum; whereas much of the latter is obtained by heating the same sulphuret of tin with equal parts of cinnabar, which affords at the same time both oxygen and sulphur to the tin.

40. Frequently when tin deprives the other metallic oxides of their oxygen, it does not take it entirely, but only divides it with them; so that in that case there results from their mutual action a kind of middle or mixed oxide, which nevertheless changes the properties not only of the tin, but of the original oxide to which the tin is applied. The least oxidized oxides of tin, exhibit the same fact; frequently in order to saturate itself with oxygen, these absorb only part from the foreign oxides, with which they are placed in contact, and from this action there results a common equilibrium of oxidation, which produces a number of particular phenomena; such especially are the mutual or reciprocal precipitations of several metallic solutions by that of tin, which in general take place, because the latter being surcharged with oxygen, can

can no longer remain united with the acids; whereas the others, being deprived by it of the proportion of that principle which rendered them soluble, cease to be suspended from this kind of defect. We have an instance of this in the formation of the purple precipitate of gold, of which I shall speak in the history of this last metal. There are no metals but manganese and zinc which take oxygen from tin; zinc, therefore, is used to precipitate tin, in the metallic state, from its solutions in the acids.

H. *Action upon the Acids.*

41. In general tin decomposes, with more or less facility, the acids, or the water which accompanies them, and tends rather to separate afterwards, in the form of oxide, than to remain united in permanent salts to the acids themselves. We might affirm, that in this strong oxidation it assumes the acid character; and many modern authors have adopted this acidification of tin, though they have not yet afforded very conclusive proofs. In consequence of this strong action of acids upon tin, and the slight attraction of its oxide for the acids, the history of its solutions exhibits so many uncertainties, variations, and even contradictions in authors, since Kunckel, who first described at length this kind of chemical compositions, and Monnet, who has very much studied them before the establishment

establishment of the pneumatic doctrine. The confirmation of this last doctrine has removed most of those difficulties, and rendered it very easy to explain the theory of the mutual action of the acids and tin.

42. Kunckel, who in this respect was copied by Juncker and Wallerius, affirmed that four parts of concentrated sulphuric acid, united to one part of water, dissolve one part of pure tin in filings. He exposed this mixture in a glass vessel, upon a sand-bath, which he heated gently, so as not to boil the acid; according to him sulphureous vapours were disengaged. The metallic form of the tin disappeared, and it gradually became dissolved; the liquor became white and thick; and when entirely evaporated, there remained a tenacious mass, which adhered to the vessel. By adding water to this cold mass, and heating it again, it was dissolved. The same transparent solution of a brown-yellow, may be made by throwing tin, in small portions, into sulphuric acid, not too much diluted, and waiting till the last of them is dissolved. Wallerius announced also, that the native crystals of oxide of tin, ziun-graupen of the Germans, are soluble in the sulphuric acid; that by adding hot water, and filtrating and evaporating, transparent crystals of jovial vitriol or sulphate of tin may be obtained, which he has not described any more than the other authors who have since mentioned it. Macquer and Citizen Baumé have added to this first description

cription, that sulphur is separated in the operation, and floats, in drops, on the surface of the hot liquor; and that it was this which gave the blueish colour to the solution. Citizen Monnet obtained by cooling, crystals in needles, which he compared to those of the sulphate of lime; he has also observed, that, in the course of time, an oxide of tin is deposited, which is no longer soluble, and can be separated in a very refractory state, extremely difficult to be reduced by the mere action of heat. It is, in fact, known by experience, that tin easily decomposes sulphuric acid somewhat concentrated, and by the assistance of heat; that much sulphureous acid gas is disengaged; and that by its strong oxidation it is capable afterwards of being separated, or precipitated by water; that when diluted, and somewhat weakened, this acid also acts upon tin, even without heat; that in this case of the least oxidation, its solution is rather more permanent, and does not become turbid by water; but if concentrated by fire, the oxide falls down; that the true sulphate of tin, in the crystallized and permanent state, cannot be obtained; that sulphur is deposited during this action; that this solution sometimes assumes a dense form, and the appearance of a white and opaque jelly, and that in this manner there is no true solid union between the oxide of tin and the sulphuric acid; nevertheless, this solution, when made without heat, and not concentrated, nor over-loaded with tin, when it does

does not become turbid by water, affords, by the alkalis and earths, a precipitate of a white, very refractory oxide, of extremely difficult reduction. The hidro-fulphurets, and the alkaline fulphurets precipitate it of a blackish brown, and lose their odour; and this precipitate, slightly heated in a close apparatus, gives aurum musivum, or hidro-fulphurated oxide of tin.

43. The action of the sulphureous acid upon tin, has not yet been described by any chemist. In the course of experiments on the metallic fulphites, which I made, together with Citizen Vauquelin, this combination exhibited some remarkable facts: I shall describe them here concisely, because they resemble those which are obtained with iron, and which being still more interesting, will be treated much more at large under that article. As soon as the tin comes in contact with the liquid sulphureous acid, it assumes a yellowish colour similar to that of aurum musivum. A few days afterwards it becomes black like charcoal, and lets fall in the fluid a black powder. The action between these two bodies then ceases. The white powder affords sulphureous acid gas by the sulphuric acid, and sulphurated hydrogen gas by the muriatic acid; this last separates the sulphur from the powder while it dissolves the tin. Before the blow-pipe this same powder melts into a black mass, after having emitted sulphureous acid, and throws out upon the edges

edges of the spoon a yellow powder of sulphur. The portion of tin blackened at the bottom of the sulphureous acid, being rubbed between the fingers, emits a strong smell of sulphurated hydrogen gas; before the blow-pipe it emits sulphureous acid, and leaves sulphur on the surrounding support. The supernatant fluid above the white and black powder, has a strong smell of sulphureous acid, which it loses in the air, and it deposits, by the addition of concentrated sulphuric acid, a portion of sulphur which is nearly pure.

From these facts it is proved, that tin decomposes one part of the sulphureous acid, which affords oxygen to it, and being once oxidized, it unites with another part of that acid; that a portion of the sulphur is deposited with the white sulphite of tin, of sparing solubility: that another remains in solution in the fluid with a little sulphite of tin, which, as we find, is a sulphurated sulphite; lastly, that a third part of the sulphur combines with a portion of the metallic tin, in the form of a black sulphuret, upon which the sulphureous acid has no action: and which stops or limits the solution, as has been observed.

44. The nitric acid is attacked with violent energy by tin. This metal is changed into an oxide of the most beautiful white, which gives to the fluid the appearance of curdled milk or cream. Chemists have long been acquainted with this lively action, and have considered

sidered it very justly as a kind of inflammation. But as they always sought to obtain solutions in the acids without looking beyond this suspension, to ascertain what happened with regard to the metal, they were long occupied in attempts to render the solution of tin in the nitric acid permanent. Citizen Baumé, from his experiments, has concluded, that the thing is impossible. Wasserberg pretended, nevertheless, that he had succeeded by adding a very small portion of tin to very pure nitric acid, diluted with water; he affirms, nevertheless, that this solution, which he says he kept a long time without its being turbid, did not afford crystals; and, that by a gentle evaporation, the whole of the oxide of tin fell down, and left the fluid pure and acid.

This fact was long ago observed by Rouelle the elder. It is certain, that by putting a small fragment of solid tin into a large quantity of nitric acid, a complete solution may be effected, and that the acid long retains the oxide, which is separable, usually, either by the addition of a great quantity of water, or by evaporation of the fluid, or when new tin is added, as if to saturate the acid: but this is not the object of research with modern chemists; they have other views in examining this mutual action of tin and nitric acid with the greatest care, on account of the important phenomena it exhibits.

Being well persuaded, from all the known facts, that tin is strongly oxidized by this acid,
which

which it decomposes with astonishing rapidity, and with which it cannot remain combined in the form of nitrate, whence it incessantly tends to separate, they have directed their attention to the oxide of tin afforded by this action. Being convinced, with Macquer, that it becomes nearly incapable of reduction, and having discovered since the death of that celebrated chemist, the cause of that phenomenon in the solidity which the oxygen assumes, and in the strong adherence it contracts with the tin in proportion as it is taken from the nitric acid by that metal, some of them have thought, moreover, that this oxide assumes the character of an acid, and that it was for this reason it could not remain united with the nitric acid. They have also been more confirmed in their opinion by the solubility of this oxide in the alkalis; and in this manner it was that Citizen Guyton understood that Klaproth had succeeded in treating and analyzing the native oxide of tin by pot-ash: he considers this solution of the ore of tin in water, by means of alkali, as a stannate or stannite of pot-ash; but notwithstanding the probability and agreement of this opinion with the foundation of the French doctrine, it is still without direct proof sufficient to adopt it, and we cannot compare the properties acquired by the oxides of tin with those of the arsenic, tungstic, molybdic, and chromic acids.

Citizen Guyton made a valuable discovery respecting the force with which tin absorbs oxygen

gen in its nitric solution. One part of the pure nitric acid, and one part and half of tin, treated in a retort, afforded him no gas, though there was a very evident action between the two bodies. Having carefully examined the residue of this operation, he found that ammonia composed nearly a twentieth part of the entire weight of the acid and the tin employed. This ammonia could be no otherwise formed than by the azote of the acid, united with the hydrogen of the water: the tin, therefore, being very greedy of oxygen, had not only decomposed the nitric acid, but also the water; and there was no disengagement of gas on account of this union of the hydrogen with azote.

45. The oxide of tin prepared or made by the nitric acid, being treated in a dose of three parts of itself with two parts of sulphur, in a glass retort, afforded Pelletier sulphureous acid and aurum musivum; whereas the oxide of tin, when less oxidized, such as the grey oxide or putty, when treated with sulphur, afforded only sulphuret of tin on account of the little quantity of oxygen it contains in that state of feeble oxidation. Three parts of sulphuret of tin, urged by heat, and to dryness, with the nitric acid, (a treatment which, in the necessity of heat for effecting the oxidation, proves, that the sulphur united to tin greatly moderates its properties of acting upon the acid in the way of decomposition,) being afterwards heated, in a retort, with two parts of sulphur, likewise afforded this skilful chemist aurum musivum, or sulphurated oxide

oxide of tin, of a gold colour. The same sulphuret of tin mixed with two parts of sulphur to three, and distilled with concentrated sulphuric acid, afforded him sulphureous acid as its product, and hidro-sulphurated oxide of tin, of a gold colour, as its residue. Pelletier accordingly availed himself of the oxidizing property of the sulphuric and nitric acids upon tin, to favour the union of that oxide with sulphur, and to prepare that brilliant, and apparently golden compound, long known by the name of aurum musivum.

46. The concentrated smoking muriatic acid acts strongly upon tin, and is, of all the acids; that which dissolves it the best. This solution is effected, even in the cold, or by the assistance of a gentle heat; the acid immediately loses its property of smoking, and the yellow colour it so often has, and we shall soon remark, that this discolouration by tin, as well as by the other bodies greedy of oxygen, affords a new proof that the colour of this acid depends on a small portion of oxygenated muriatic acid. The slight effervescence which takes place during this decomposition, is owing to the decomposition of the water, and the disengagement of a fetid hydrogen gas of which the nature is not yet known, and of which the examination may probably hereafter afford some fortunate discovery respecting the composition of the muriatic acid. I suspect that the odorant and fetid gas which is disengaged in this operation, is hydrogen gas, holding tin in the æriform solution.

great number of experiments, all which proved that it is capable of absorbing oxygen very powerfully from a number of bodies, and of passing to the new state of super-oxygenated muriate of tin, possessing other properties, and among them that it becomes of a quality very superior for most of the operations of dyeing. The following is a sketch of his discoveries in this respect.

a. The solution and muriate of tin absorb oxygenated muriatic gas with heat, at the same time that the gas loses its smell, and causes a change in the nature of the solution.

b. It makes a violent effervescence with the nitric acid, disengages much nitrous gas, and is frequently thrown out of the vessel by this addition.

c. It becomes reddish by the sulphureous acid, and deposits sulphurated oxide of tin, which is of a very beautiful yellow colour.

d. It blackens and changes into metal the arsenic acid; it renders blue, and causes to pass to the metallic state, the molybdic and tungstic acids, the tungstate of lime and ammonia, by depriving these three acids of oxygen.

e. The red oxide of mercury, and the super-oxygenated muriate of mercury, thrown into this solution, also yield their oxygen, and pass to the metallic state.

f. The same effect takes place with the white oxide of antimony, that of zinc, and that of silver.

g. It

g. It decomposes the solution of gold, and precipitates the purple powder of Cassius, by seizing the oxygen which rendered that metal soluble, an effect which it does not produce when saturated with oxygen.

h. Lastly, it immediately absorbs oxygen gas, and passes to the same state as if it had been mixed with oxygenated muriatic acid; this fact induced Pelletier to consider it as very proper to afford chemists a means of determining the quantity of oxygen gas contained in an æri-form fluid.

i. He proposed to make the composition for dyeing by charging the solution of tin with oxygenated muriatic gas; he observed that this solution absorbs the gas almost to the amount of half the weight of the tin it dissolved. It must afterwards be heated on a sand-bath, to separate the portion of disengaged muriatic acid, which it contains after this absorption.

48. The results of these interesting experiments are found to agree with other researches no less curious and agreeable to the pneumatic doctrine which Citizen Adet made four years before, upon a kind of fuming muriate of tin, denominated liquor of Libavius, from the name of its first author. Though this singular product be the result of the decomposition of the super-oxygenated muriate of mercury by the tin, it has too direct a relation with what has been explained, for us to omit the exhibition in this place of its preparation, and the comparative

comparative properties of the two muriatic solutions I have described: so many opportunities have presented themselves to remark the strong attraction of tin for oxygen, that it is unnecessary to explain the theory of this decomposition. When equal parts of an amalgam, made with two parts of tin, and one part of mercury, for the purpose of dividing the tin, and of the corrosive muriate of mercury, are triturated together, and the mixture is distilled in a glass retort, by a very gentle heat, a colourless liquor first passes over; after which, with a sort of explosion, and at one single jet, there is thrown out a thick vapour, which covers the receiver with a very thin coating. This fluid is condensed into a transparent fluid, which exhales in the air a white, heavy, and very abundant fume: it is the fuming liquor of Libavius, or the super-oxygenated and fuming muriate of tin. While enclosed in a bottle this fluid emits no visible vapour; it nevertheless deposits, at the upper part of the vessel which contains it, needle-formed crystals, which frequently close the aperture; a portion of these crystals is also precipitated to the bottom of the fluid. In the air it fumes much, and emits an acrid odour, which excites coughing; it is to the atmospheric air which produces a precipitation of the oxide of tin that this vapour is owing. Water, however, does not precipitate this liquid fuming muriate of tin; when it is poured into water, a considerable noise is produced, similar to that occasioned

sioned by the concentrated sulphuric acid, it separates immediately into many transparent bubbles, which escape from the mixture and rise to the surface of the water, where they break into a gas, which becomes white by the contact of the air. By agitating the water they are more speedily dissipated, and the fluid no longer fumes. Macquer affirms, that when diluted with much water, the fuming liquor throws down an oxide of tin in small, white flakes. The residue of the distillation of this super-oxygenated and fuming muriate of tin, also presents various interesting phenomena, which have been well described by Rouelle the younger. The roof and the neck of the retort are coated with a white and grey covering, containing a small quantity of fuming muriate, besides another portion of concrete muriate of tin, which was formerly called corneous tin, with mild muriate of mercury, and running mercury. The bottom of the same vessel contains an amalgam of mercury and tin, covered with solid muriate of tin, of a white grey, which may be volatilized by a stronger heat than that which is necessary to obtain the fuming muriate. When the solid muriate of tin is again treated in the retort, it melts and separates into two strata: the one, which is black, occupies the lower space, and the other white, is similar to the former sublimed muriate of tin, or corneous tin. From these details we see that in the operation of the fuming liquor of Libavius the tin

seizes the oxygen from the mercury, and divides itself into a number of oxides, more or less charged with that principle, which form different combinations with the muriatic acid.

49. Citizen Adet has subjected the fuming liquor of Libavius to a number of experiments which exhibited its nature with precision. The principal are the following:

a. When this liquid is united with water, a disengagement takes place, by a true effervescence of bubbles of azote gas, the origin of which it is not easy to determine, and which the author himself did not endeavour to ascertain.

b. When combined with water, in the proportion of about a third of the weight of this liquid, or in the proportion of 7 to 22, the fuming liquor forms a solid body, fusible by fire, congelable by cold, and resembling that which chemists formerly called butter of tin.

c. This fuming muriate of tin, diluted with water, dissolves tin without effervescence or motion, without producing or disengaging hydrogen gas, and affords a salt in every respect similar to that which the immediate solution of tin in the muriatic acid produces.

The chemist here cited concludes, from these experiments, that the fuming liquor is a compound of muriatic acid disposed to take the æri-form state, and of super-oxygenated oxide of tin; that it is with regard to the ordinary muriatic solution of tin, the same thing which the corro-

five muriate of mercury is to the mild muriate, or that it is a super-oxygenated muriate of tin. Pelletier, from his experiments concludes also, that the muriatic solution of tin charged with oxygenated muriatic gas, which it decomposes by seizing its oxygen and deprived of the muriatic acid in excess which it then contains by means of heat, is entirely similar to the fuming liquor diluted with water; and it is evident, that he arrived at the same result as Citizen Adet, by experiments made absolutely in an inverse process. He announces, that the super-oxygenated muriatic solution of tin, prepared by his process, crystallizes by evaporation, and totally sublimes, like the fuming muriate of tin mixed with water. Another observation will still more confirm the similarity of the theory of these two muriates of tin, of which I have exposed the difference and the properties. It is so clear, that the muriatic solution of tin owes its properties of precipitating gold in a purple powder to its tendency to deprive it of its oxygen, that, if left to the air for some time after its preparation, it loses this property on account of the atmospheric oxygen it absorbs: whence it follows, that the views according to which, we may prepare this solution are truly inverse, the one of the other, when it is intended for the precipitation and brightening of colours or to precipitate gold from its solution in purple oxide, as I shall hereafter show under the article of this last metal.

50. Tin thrown in filings into the oxigenated muriatic acid, takes fire, and becomes strongly oxidized. This liquid acid oxides it, and dissolves it without motion or efferverence. According to the mutual proportions of these two bodies, we may make either muriate of tin, or super-oxigenated muriate of tin; the first precipitates gold of a purple colour and eudiometrically absorbs the atmospheric oxygen; the second exhibits neither of these properties. By a single fact, therefore, we confirm the whole of the theory before explained.

51. The nitro-muriatic acid, particularly that which is made with one part of nitric acid, and two or three parts of muriatic acid, easily dissolves tin. This mixed acid has even almost always been considered as its true solvent. It excites a strong heat which may be diminished by plunging the vessel in cold water. The metal is not to be added but by portions at a time, in order to have a permanent solution, and one part must be suffered to dissolve before another is added. The nitro-muriatic acid can in this manner dissolve half its weight of tin. It is easy to conceive, from what has already been remarked, that this solution must vary according to the proportion of the two mixed acids, and that it may be more or less oxigenated according to the quantity of nitric acid which is added. Hence arises the difference of effects, which is so often found in this solution, in the arts and manufactures wherein it is used, according

cording to the process, with which it is prepared. It is almost always coloured; it often forms a tremulous gelatinous substance by cooling; it then assumes a solidity, which becomes stronger with age; sometimes it is transparent, sometimes white, and semi-transparent like an opal; it has not the fetid smell of the simple muriatic solution, and does not exhibit the gelatinous concretion, except when loaded with oxide of tin. It happens, nevertheless, very frequently, that it only assumes the viscid and half-concrete form, when half its weight of water is added: it is then always somewhat opaque, which depends, as Macquer affirms, upon the precipitation of part of its oxide. When heated rather strongly, this solution again effervesces, which shows a new mutual action between its principles, and a stronger oxidation of the tin. It is particularly after this phenomenon, that it acquires the form of transparent jelly. It is evident, that the muriate of tin is then super-oxygenated.

52. The phosphoric acid has scarcely any action upon tin when in the liquid form and cold. The soluble phosphates, poured into the muriate of tin, afford a precipitate of phosphate of tin. The vitreous phosphoric acid heated with half its weight of tin becomes decomposed; it then forms one part of vitrified phosphate of tin, and another part of phosphuret of tin, similar to that which is immediately made by the addition of phosphorus to fused tin. Pelletier, who discovered this combination concludes,

cludes, that tin has more attraction for oxygen, than phosphorus has. But in this case there is an equilibrium of combination, on one side between a portion of the oxidized tin and the vitreous phosphoric acid, and on the other between a portion of phosphorus separated from the acid and the metallic tin, an equilibrium which is established at the instant when each of these compounds is formed; and we cannot doubt but this double combination is the cause of the limited decomposition of the phosphoric acid.

53. The action of the fluoric acid upon tin has not yet been examined; it has even been thought so weak that retorts of tin have been proposed for distilling this acid. This was the opinion of Puymaurin of Toulouse, in his Memoir on the art of using this acid to engrave upon glass, who affirms that he used vessels of this metal to distil the fluoate of lime by sulphuric acid. This acid unites by double attraction to the oxide of tin, when a solution of a soluble fluoate is poured into that of the metal by the muriatic acid. The acid of borax does not combine with it but by the same process, and forms an insoluble borate. The carbonic acid has no sensible effect upon tin, either in the form of elastic fluid or the liquid form; it nevertheless unites with its oxide when the muriate of tin is precipitated by an alkaline carbonate; and when this white carbonate of tin is re-dissolved in an acid, it exhibits an effervescence.

veſcence. It has been thought that this ſalt exiſts native, but no poſitive fact has yet proved it.

54. The metallic acids are all capable of being decompoſed by tin, which has more attraction, particularly with the aſſiſtance of heat, than thoſe metals have for oxygen. But theſe acids unite with the oxide of tin, and form with it pulverulent ſalts, which are not at all ſoluble, and of which the properties have not yet been examined. We may ſuſpect that theſe ſalts exiſt in nature, though they have not been found among foſſils.

Action upon the Baſes and upon the Salts.

55. THE habitudes of tin are nearly the ſame as of zinc with the cauſtic alkalis; it is nevertheless ſomewhat leſs alterable by thoſe baſes than the latter metal, and it does not like it afford hydrogen gas, becauſe, though very oxidable, it is much leſs ſo than zinc. But though tin is leſs alterable in its metallic ſtate by the alkalis, it combines much more readily with them in its ſtate of oxide. I have already ſpoken of this combination under the article of aſſays, and that of the ſolutions by the acids. The union of the oxide of tin with the fixed alkalis takes place in the dry way, as well as in the humid way; it alſo takes place with liquid ammonia

ammonia by means of heat. It must be observed that this effect is not well produced, unless the tin be minutely divided, as for example, at the moment when it is precipitated; but that when it is dense, and presents a strong aggregation between its particles, as is the case with most of the ores of tin, we must avail ourselves of the dry way to unite it to the pure fixed alkalis.

56. The oxide of tin combines with the earths by fusion, and becomes vitrified with them by means of a fixed alkali, in such a manner however as to form an opaque composition called enamel. The whiteness which this oxide when very pure possesses, and the opacity it, at the same time, communicates to glass, have caused it to be much used as the basis of enamel. Chemists have thought with regard to this composition, that the oxide of tin, undergoing a true vitrification, is uniformly diffused between the particles of the glass, and remain disseminated like starch in paste.

57. Most of the salts are more or less decomposable by tin on account of its strong attraction for oxygen. All the sulphates heated with this metal are more or less speedily and easily converted into sulphurets. When equal parts of pot-ash and this metal were heated in a crucible, I obtained a greenish fused mass, as we have seen with antimony and zinc, and announces in those three metallic substances a strong tendency to unite with oxygen, and to decompose

decompose the sulphuric acid. Glauber in the last century made this observation upon the ammoniacal fulphate.

58. The nitrates all burn tin with more or less force and speed by the assistance of heat. This combustion is usually effected by melting and obscurely igniting tin in a crucible, upon which nitre or very dry nitrate of pot-ash is thrown. A white and brilliant flame rises above the crucible. When the detonation is ended, when there is no more flame excited by the projection of the nitre, the tin is totally oxidized. This oxidation is still better performed by mixing tin in fine filings with three parts of nitre, and projecting the mixture into a red-hot crucible. After this operation a very white oxide of tin remains, which is partly united with pot-ash. By lixiviating this residue with water, the fixed alkali is washed off in combination with a small quantity of oxide of tin, which may be precipitated by an acid. We also find in this lixivium a small quantity of nitrate of ammonia, formed by the simultaneous decomposition of the nitric acid and water, similar to the salt which Bayen obtained by washing the oxide of tin afforded by the nitric acid. Geoffroy observes, that the grey oxide of tin detonates with nitre; a fact which proves that this oxide is not saturated with oxygen, and that it is still very much disposed to absorb that principle. On account of this it is that the oxide decomposes nitre in a retort, and disengages nitrous

trous acid, as Pelletier observed; and that after this decomposition, the oxide which results is susceptible of affording aurum musivum with sulphur on account of its strong oxidation, whereas the grey oxide affords none. The nitrate of pot-ash is not decomposed by the white oxide of tin, which was formerly called flowers of tin, and is the product of the complete oxidation or deflagration of that metal.

59. Some chemists have affirmed that tin decomposes the muriate of Soda; but they have not stated accurate experiments in support of this assertion; but it decomposes the ammoniacal muriate very well on account of the volatility of its base, together with the strong action of the muriatic acid upon the metal. Bucquet has made this experiment with great care. By distilling the muriate of ammonia with half its weight of tin in filings in a glass retort, he obtained much hydrogen gas mixed with ammoniacal gas. This decomposition is never complete, because the tin melts, and is collected in a button in the retort. The residue of this operation is a solid muriate of tin decomposable by water, and similar to that which is afforded by the distillation of corrosive muriate of mercury and tin before spoken of.

60. The golden sulphurated oxide of tin or aurum musivum is prepared by decomposing the muriate of ammonia by tin, and adding sulphur to the decomposition. Since the time of Kunkel, who first described with particularity this singular

singular operation and its most singular product, his process has been pretty constantly employed, which consists in heating in a retort equal parts of tin, of mercury amalgamated with tin, of muriate of ammonia and of sulphur. Bullion found that the proportion of sulphur might be diminished a little, and that of sal ammoniac still more. Pelletier, who has repeated the process of Bullion, obtained a very beautiful aurum musivum, by heating eight parts of tin united with eight parts of mercury, together with six parts of sulphur, and four of muriate of ammonia. This skilful chemist has observed that sulphurated hydrogen gas is disengaged in this operation, together with sulphuret of ammonia and muriate of tin; that the tin being oxidized and united to the sulphur constitutes the aurum musivum; that a portion of this combination, formed by the substances in the state of vapour, is deposited in lamellated hexangular crystals against the roof and in the neck of the retort; that aurum musivum is not itself volatile; that it is decomposable by a strong heat, and affords sulphureous acid, and that at the same time that it passes to the state of sulphuret of tin; that this product might be fabricated by heating the sulphuret of tin with equal parts of sulphur and sal ammoniac; that it might also be obtained with equal parts of sulphuret of tin and super-oxygenated muriate of mercury heated together; that this compound contains sixty parts of oxide of tin, and forty of sulphur, whereas

whereas the sulphuret of tin contains only twenty parts of sulphur united to eighty parts of metallic tin; that the sulphurated oxide of tin when heated with charcoal is decomposed, affording carbonic gas with sulphurated hydrogen gas, and that it becomes reduced to the state of sulphuret of tin, by the loss of sulphur and oxygen in this process; that this aurum musivum is not changed nor enlivened as to its colour by the muriatic acid, whereas the sulphuret of tin is strongly attacked by this acid: lastly, that in order to prepare this brilliant compound, we might with advantage substitute, instead of the retort hitherto employed, a crucible filled to one-third of its height, with the mixture made in the proportions indicated by Bullion: at the distance of one inch above the mixture he placed a grooved cover of pottery: on this vessel he placed a second covering luted on; and this crucible was placed in another larger one full of sand; he heated the whole apparatus in a furnace for eight or ten hours, with the temperature necessary for the sublimation of muriate of ammonia. The crucible when broken exhibited one part of the sublimed salt, and underneath a blackish mass was found, the aurum musivum in a solid form of a beautiful golden colour. He informs us that the black substance may be used in successive operations.

This process, as Pelletier remarks, is much easier, and more particularly less expensive than
the

the ancient method. Four parts of tin, made use of, afford five parts of the fulphurated golden-coloured oxide, which is used either for ornaments or decorations, or to rub the cushions of electrical machines. These important results of the capital experiment of Pelletier, united to several of those which I have exhibited in the preceding numbers, render the history of aurum musivum complete. I shall only add, that this compound is not a simple fulphurated oxide of tin; but that it contains hydrogen, as all the experiments of this chemist prove; for which reason I have called it the hidro-fulphurated oxide of tin.

61. The super-oxygenated alkaline muriates, particularly that of pot-ash, which is the only one well known, and hitherto employed in experiments, burn, enflame, and oxide tin much more strongly than the nitrates do. Three parts of this salt mixed with one part of tin, in fine powder, take fire rapidly by the contact of an ignited combustible body. In this combustion there is a lively and sudden flame; the tin is reduced into vapour as if by the electric spark, when the experiment is made in the open air. When it is made in closed vessels, it affords a method of obtaining very pure oxide of tin, and of knowing exactly the quantity of oxygen it contains, after washing the residue; which washing carries off the muriate of pot-ash alone, without any portion of the oxide. When a mixture of super-oxygenated muriate of pot-ash
and

and tin is struck upon a mass of steel, it fulminates with a loud noise and a large luminous circle in the dark.

62. Tin decomposes a great number of salts and metallic solutions, either by precipitating the metals in their brilliant and metallic form, when it takes from them all the oxygen they contained, or by separating them in the state of oxides less oxygenated than they were before; and in this last case either it is precipitated with them by the union of the oxides, or it takes their place in the acids, from which it separates them. By either of these means it produces very remarkable phenomena, of which chemists have availed themselves in their analyses, and from which the arts possess the advantage of a number of useful products.

K. *Uses.*

63. THE uses of tin are extremely multiplied, and we may affirm that there is not a metal which is more important or useful to society. It is made into vessels of every description, and moulds for a great number of the arts. It serves for lining boxes and vessels used in a great number of circumstances. The pipes of organs are made of this metal, and it is the principal ingredient in the plates upon which music is engraved. Decorations of a very lively appearance are formed of tin, and it is applied

applied in thin leaves to a great number of philosophical instruments, more especially those which are used in electricity.

64. Its alloys are equally advantageous to the wants of the community. The amalgam of tin is used for glasses and mirrors. It is an ingredient in solder, and applied to the surface of copper to defend it from corrosion. When intimately alloyed with this last metal, it serves for casting statues, bells, cannon, medals; it enters into the composition of the metals used in polytypage and stereotypage. Pewterers use it with bismuth, antimony, lead, and copper, to give it consistence, hardness, and to form utensils of every description employed in a great number of uses. It enters in general into many white alloys, more or less ductile or brittle, hard or soft, fusible or refractory, &c.

65. Its oxides, under the name of putty, serve to polish a variety of hard bodies: they are melted with the oxide of lead, sand, and fixed alkalis, to fabricate enamel, to cover, varnish or glaze pottery, porcelain, plate glasses, and the false semi-transparent stones. The muriate of tin is used to prepare the fine purple named the precipitate of Cassius, of which I shall speak under the article of gold: the super-oxigenated muriate of tin, is one of the most valuable ingredients, and mordants of dyeing, under the name of composition. It is no less useful in the calico printing. Its application has made an immense progress in those interesting arts which

which are at present the instruments of prosperity and riches in cultivated nations. It is to this metal we owe the brilliant shades of scarlet, deep poppy-colour, and brilliant fiery red. Its advantageous properties will, no doubt, be carried to still greater and more extensive degrees of utility.

66. The use of tin in culinary utensils, in pharmacy, and in all the wants of life, has been falsely considered as dangerous, from the erroneous experiments of Geoffroy and Margraff. It is well proved, as I have shown, that it does not contain the arsenic admitted by those chemists, respecting the presence of which they were singularly deceived, as appears from the conclusive researches of Bayen. It is no longer possible to entertain any doubt respecting the ill-founded nature of those apprehensions, or to listen to the false declamations, so often repeated for fifty years, concerning this metal. Schultz, in his well-written dissertation on the use of vessels of metal, in the preparation of food and medicine, had already vindicated tin from the absurd calumnies applied to it, and the experiments of those French chemists I have already cited, add to the reasonings and to the assertions of Schultz a degree of force and authority which can never hereafter be weakened or overthrown.

So that notwithstanding the condemnation which some men, deceived by their false experiments, had inflicted on this metal, many physicians had proposed and employed it, even with success,

success, in disorders of the liver, the womb, and affections caused by worms. La Poterie prepared his anti-hectic from this metal, which, during a number of years, was greatly in fashion, and was only a lixivium of the oxides of antimony and tin, formed by detonation with the nitrate of pot-ash, that is to say, a solution of pot-ash, containing a portion of these oxides. Country people frequently leave for twenty-four hours sweet made wine in a vessel of tin, and give a glass of this liquor to their children who are attacked with the worms. Navier saw a girl of sixteen years who evacuated thirty worms, by the effect of this remedy.

The powder of tin is used at Edinburgh and in England, in disorders arising from worms, for which purpose it is made by pounding the metal in the fused state in a mortar, and preventing it from assuming the solid form, after which it is passed through a fine sieve. In this country tin is a remedy very commonly known, and of which the effects are much extolled.

ARTICLE XVIII.

*Of Lead.**A. History.*

1. LEAD, like tin, is one of the metals which men have the earliest known, and which appears to date in the earliest periods of human civilization. The time of its first use is lost in the night of the earlier ages, and the most ancient authors speak of it as a metal already employed from time immemorial. Tradition even among the remotest nations, gives no information, as it should appear, concerning the origin and discovery of lead.

Pliny speaks of it under the name of *plumbum nigrum*; and though it was known only by a few of its properties, he has distinguished it very well from tin, and has remarked that the latter was even then falsified or adulterated with the former. We shall be less surpris'd at the antiquity and the uses of lead, than that of the discovery of tin, if we compare the abundance of the ores of the former, and the facility of treating them, with the rarity and difficulty of treating the ores of the latter.

Alchemists have compared lead to Saturn, not only because they suppose this metal to be the oldest, and, as it were, the father of all the others,

others, but also because it was considered as very cold; because the property of absorbing and apparently destroying almost all the metals, was attributed to lead in the same manner as fabulous history affirms that Saturn, the father of the Gods, devoured his children. The sign of lead is the same as that of the planet Saturn, formerly represented by a crescent placed below and to the right, and surmounted at the left by the cross, the image of the reddening and acid quality. It signified, according to the alchemists, that by certain concealed analogies with sulphur, it was almost entirely corrosive; which proved, according to them, its destructive, and, as it were, narcotic effect on the animal economy. This metal has been more particularly tormented by experiments by the alchemists, and they have left us a great number of processes respecting it. They pretended to convert it into silver, and it is one upon which, according to them, the powder of projection has the greatest effect.

3. To the singular and unhappy labours of the alchemists on lead, succeeded those of the pharmacological chemists, who proposed to themselves an object no less chimerical, but at least more useful and philosophical; namely to mask or destroy the noxious properties of this metal, and render it advantageous in the art of healing. Their efforts, though not entirely fruitless, have not produced the success they sought. The preparations of lead, in whatever manner they were made still retained their destructive and paralyf-

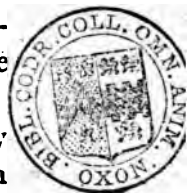
ing property ; it has never been advantageously applied in medicine, but as a topical remedy : even in this case, its administration requires great prudence, and ought not to be entrusted but to men of skill. Nevertheless, while the earlier chemists thought to mitigate the acrid nature of lead, and make experiments upon it for the objects of pharmacy, they discovered many of its properties, and contributed much to its chemical and philosophical history.

4. Authors of systematical publications upon chemistry, have availed themselves of these several preliminary works, in order to determine the particular and characteristic properties of lead. Each of these authors, particularly those who have drawn up their treatises after the experimental demonstrations they have made upon the science, (and it may easily be imagined, that those alone are capable of giving an account of the whole science, as well as its particular parts) has enriched the history of lead with some discoveries, or certain series of researches or assays peculiar to himself. Thus we have gradually seen the details of processes, experiments, and results respecting lead increase in the successive works of Barner, Bohnius, Stahl, Boerhaave, Juncker, Shaw, Macquer, Wallerius, Spielman, Cartheuser, Baumé, and particularly the more modern treatises of Wafferberg and Gren, who have added their own proper experiments to those of their predecessors.

5. Mineral-

5. Mineralogists, assayers and metallurgists, have also united to complete the history of the chemical properties of lead. In this respect, it is even a metal which has been more especially studied, and is one of the best understood with regard to its assays and the operations upon it. Though it has not been, any more than tin, considered chemically by any historian, who has confined himself to the subject singly, we find in chemical works great numbers of dissertations on some of its properties or combinations, or some parts of its multiplied and highly important uses. Its assays, its solutions, its oxides, and its alloys with the other metals, considered with respect to the arts, have been more particularly treated of.

6. The pneumatic doctrine has afforded many developments, and tended greatly to enlighten our knowledge of the properties of lead. Upon this metal it is that philosophers have fixed their earliest attention with respect to the increase of the weight of its oxide, and sought to ascertain the cause of this augmentation, the difference of the several oxides it affords, the theory of their reduction by carbon, the action of the acids upon this metal, the manner in which it is altered by the salts, the characters and the composition of its ores, and particularly, the various native salts of which it is a component part. The effects of these oxides upon saline substances, have been the source of several modern discoveries, which, while they add to



the accuracy of its individual history have also concurred to strengthen and confirm the bases of the pneumatic doctrine. We are more particularly indebted to the later researches of Proust, Professor of Chemistry at Segovia, and Citizen Vauquelin, on the different oxides of lead, and their action in the decomposition of salts, for the clearness and perspicuity of our knowledge relative to the chemical properties of this metal.

B. Physical Properties.

7. LEAD, which a few years ago, was considered as a base, ignoble, imperfect metal, is of a grey colour, dull, or of little brilliancy, and very perceptibly inclining to blue. It resembles no other metallic substance as to this property; its colour is livid, and as it were, sad; it seems to announce its dangerous qualities; and instead of attracting the eye, as the colour of other metals does, it, in some measure displeases, repels, and produces the idea of danger.

8. The weight of lead is considerable; compared with the other metals it occupies the fifth rank; it is placed between mercury which is heavier, and silver which is rather lighter than it. Its specific gravity is expressed by the number 11,352. water being 1,000. It is the least ductile and the least sonorous of the metals of the fourth genus; it is easy to laminate, and very readily flattens under the hammer; it does
not

not acquire much hardness by hammering. It is so soft that it may be scratched with a nail, cut with a knife, or bended in every direction. Its tenacity is the least of all the metals. A wire of lead of one-tenth of an inch in diameter supports only $29\frac{1}{4}$ of a pound before it breaks.

9. Lead is a very good conductor of caloric, though it is not extremely dilatable. It melts at a low heat, and immediately after mercury, tin and bismuth; it holds the fourth rank in the order of fusibility. Citizen Guyton estimates it at 250 degrees of the thermometer of Reaumur. When it is kept long red-hot, it sublimes and emits fumes in the air; but for this purpose a very elevated temperature is required. If it be slowly cooled, it crystallizes in quadrangular pyramids, all formed, as it should appear, of octahedrons. Thus it was that Mongez the younger obtained it. It is observable that when this operation is made, it succeeds best (as tin likewise does) when the lead has been fused several times successively.

10. This metal is a conductor of electricity and of galvanism; but it appears that it possesses these properties only in a weak degree: it has a particular and rather fetid smell; its taste is also somewhat acrid and disagreeable: in consequence of this property it should seem that it acts upon the animal economy, and produces the deadening and paralyzing action which is so well known.

C. Natural History.

11. LEAD is a metal of which the ores are very abundant in nature; there are many in France, Germany, England, &c. It is also a metal of which the ores are the most varied. Mineralogists have minutely described a great number of species; but most of them also have either spoken of the ores belonging to the other metals, or have taken varieties for species, and in that manner have multiplied individuals without necessity. Thus they have distinguished, among the sulphurets of lead, as many species as there are different metals combined with sulphur together with lead; and nevertheless while they thus multiplied the species from the properties, which ought to have given only varieties, the science has made real advances in the discovery of new ores of lead, more different from the former known species, than some of those were really with respect to each other. Hence it is that we perceive vacancies in the systems of mineralogy. Bergman, for example, in 1780, distinguished only three ores of lead, namely, the sulphuret, the carbonate, and the phosphate.

12. Though the existence of native lead in the metallic state has been admitted by Wallerius and Linnæus; though Henckel mentioned it before them in his Pyritology; though Genf-
fane,

fane, in his natural history of Languedoc, affirms that he found it in the Vivarais, and though Kirwan adds to these authorities, that of the discovery of the same native metal in Monmouthshire; yet most mineralogists, Cronstedt, Justi, Monnet, and particularly Haüy, do not reckon this native metal among the species of lead ores. Citizen Guyton, in the note he has given upon this article of the humid analysis of Bergman, observes that the lead found by Genflane in the Vivarais was grains diffeminated in the oxide, and even in the vitreous scoria: which evidently proves, according to him, that it arose from an ore reduced by fire or the burning of a forest. This notion was not destroyed when he saw a sample of lead itself taken on the spot by Citizen Groffard-Virly. He thinks the same was the case with the Monmouth native lead, described in the Philosophical Transactions 1772.

13. Neither have the alloys of lead with other metals been found in nature. It is no less a problem respecting the existence of pure oxide of lead among its ores. Three of the five states which I have indicated in general, in the natural history of the metals, are consequently null with respect to lead; it is not found in the earth, but in the state of metal combined with sulphur, or of oxide united to the acids in the form of salts of lead. This last state, though less abundant than the former, is the most frequent and the most varied of the
ores

ores of lead. I therefore admit seven very different species of lead; 1. Sulphuret, 2. Sulphate, 3. Phosphate, 4. Arsenite, 5. Molybdate. 6. Chromate, 7. Carbonate. I shall proceed to point out the principal characters of each of these ores.

14. The native sulphuret of lead is an ore very easily known by its grey, very brilliant and specular colour, its lamellated texture, its cubic form, and its brittleness. It was formerly called Galena, and is found in great abundance in continued veins in nature. It is found in cubes, insolated or grouped, in octahedrons, also insolated, and arising from the diminution of the small cubic particles on all the edges and angles at the same time, in plates very broad or narrow, in a texture as it were granulated in hexahedral prisms, or in columns which appear to be saline lead passed to the state of sulphuret. There is not a single piece or variety of sulphuret of lead which does not contain silver: sometimes the miners consider as silver ores those sulphurets of lead which are highly charged with this valuable metal. Such particularly was that which Mr. de Born in his mineralogical catalogue has nominated grey or white silver ore; the weiffgittig of the Saxons in which Mr. Klaproth found 0,40 of lead, 0,20 of silver, 0,12 of sulphur, 0,08 of antimony, 0,02 of iron, 0,07 of alumine, and a little flux; an ore very complicated, as we see in its composition, and of which complication many other

varieties of sulphuret of lead, if analyzed with the same care, would present new instances. It is observed in general that the varieties of this ore, with small facets or of a granulated texture, are more loaded with silver than the others. Those which are designated as particular species by several mineralogists by the name of martial galena, antimonial galena, ought therefore to be considered as varieties, which differ only in the proportions of their principles, or by the addition of some metals to the sulphuret of lead. By a more attentive examination it may be hereafter discovered, that the iron and particularly the lead, are only interposed between the proper particles of the sulphuret of lead, of which the abundance and predominance ought to cause them to be ranked among the ores of this last metal.

The sulphuret of lead is the most frequent and most abundant of the ores of this metal. It is found in masses, and in considerable beds at different depths frequently between two layers of blackish quartz, containing sulphur according to the observation of Citizen Dolomien. This ore is the most frequently wrought to extract the lead. Citizen Monnet has observed sulphuret of lead to effloresce, become burned in the air, and converted into sulphate of lead.

15. The same mineralogist first discovered native sulphuret of lead in a white mass, soluble in eighteen times its weight of water, or blackish striated, friable, or in stalactites. Dr.

Withering

Withering has since found it in the Isle of Anglesea in regular small octahedrons. Its colour is yellow, and it is united to iron mixed with clay. Citizen Monnet asserts that it is reducible by charcoal, and that it arises from the efflorescence and spontaneous sulphatization of certain sulphurets or friable pyrites of lead; that mentioned by Dr. Withering is not reducible either by the blow-pipe or by charcoal.

16. Mr. Gahn, a Swedish chemist and physician, the pupil of Bergman, first discovered a greenish phosphate of lead in Brisgaw. Mr. Tenant has confirmed the discovery of Gahn. Klaproth found in the lead of Brisgaw near 0,19 of phosphoric acid, and 0,73 of lead. Citizen Gillet Laumont having obtained from the yellowish crystals of lead called the spathose lead of Huelgoet, by treatment with the blow-pipe, an irreducible button, and having observed in furnaces, in which this ore is treated, a yellowish dancing flame, suspected that this spathose lead might be a phosphate, and undertook to examine it chemically. He found means by treating it with nitric acid to separate the acid of phosphorus. This phosphate of lead has the form of thick hexahedral regular prisms of a yellowish or reddish colour; it afforded Citizen Häüy, by dissection, a dodecahedron in isosceles triangles, with the prism comprehended between the two pyramids. By fusion with the blow-pipe it crystallizes in a regular polyhedron as it cools. Since the first discovery many varieties

rieties of this oxide of lead, saturated with phosphoric acid, have been discovered. We are at present acquainted with transparent, opaque, white and grey, yellow, yellowish green, and brown. I have found it in green protuberances in an ore of Pontigibaud, in the department of Mount d'Or, containing arseniate mixed with phosphate of lead. Its abundance appeared to me, to be such, that it would be easy to extract, at a cheap rate, the phosphorus on the spot where it is found.

17. The arsenic of lead, or arseniated lead, has been lately discovered (in the winter of the year 8) by Citizen Champeaux, engineer of mines; it exists either in silky filaments, of a beautiful yellow, amianthiform, slightly flexible, and very easy to break; or in thin concretions upon quartz or fluate of lime. These last are of a less decided yellow than the filaments, frequently greenish, compact, of a greasy aspect and vitreous fracture. The arseniate of lead has been found in a mountain near Saint-Prix, in the department of Saone and Loire. It is easily reduced by the blow-pipe, and speedily emits a strong arsenical vapour. Its reduction is accompanied with an effervescence, which shows that the arsenic exists in the state of oxide. Citizens Vauquelin and Lelievre have ascertained that this ore is the arseniate of lead.

18. The molybdate of lead was discovered by Mr. Klaproth in the yellow lead ore of Bleyberg.

berg. It is named yellow lead in collections. Mr. Wulfen described it for the first time in 1785. Mr. Heyer thought that he had discovered the tungstic acid; but the presence of the molybdic acid, announced by Klaproth, has been confirmed by an accurate analysis made by Citizens Vauquelin and Macquér, inserted in the *Journal des Mines*, p. 23. This native salt varies in its colour from pale yellow to orange yellow. Its fracture is semi-transparent and lamellated; it is crystallized in rectangular square plates, sometimes terminating in a bevel surface; its specific gravity 5,486. All the powerful acids decompose it; the caustic alkalis dissolve it without alteration; it is reducible by charcoal. According to the analysis of the French chemists above cited, it contains 64 parts of oxide of lead, in which there are five parts of oxygen to 59 of lead, 0,28 of the molybdic acid, 0,04 of carbonate of lime, and 0,04 of filix.

19. The chromate of lead is a new substance discovered in October 1797, by Citizen Vauquelin, and consists of the metallic acid of chrome, of which I have pointed out the properties in the fifth article of this section. This new salt was formerly known under the name of the red lead of Siberia. As I have related the history of this discovery in that of chrome, I have nothing further to state in this place, except the characteristic properties of the native chromate of lead. This mineral is of a bright lead; its powder

der is of a yellow-orange colour. Its form is that of rhomboidal striated prisms, terminating in distinct sub-tetrahedral summits ; it is very brittle. The fixed alkalis dissolve it without decomposition. The alkaline carbonates decompose it on the contrary very easily by the humid way, and form carbonate of lead, which remains insoluble, and the chromate of pot-ash or soda, which is soluble, and of a yellow, or slightly orange colour. It gives a green colour to the fluxes of borate and phosphate of soda, when fused before the blow-pipe ; it is decomposed by the muriatic acid, which affords muriate of lead in crystals, and chromic acid dissolved in water, with its orange colour. The sulphuric acid also decomposes it ; but it is difficult to separate the chromic acid. The nitric acid dissolves it by heat without decomposition, and suffers it to fall again by cooling. An hundred parts of this chromate of lead contain, according to the analysis of Vauquelin, very nearly 65,12 of oxide of lead, and 34,88 of chromic acid. Citizen Vauquelin found, besides the crystals of red lead, other green crystals which are a combination of oxide of lead and chrome in the state of green oxide. Lehman and Mongez thought that the red lead was mineralized by the arsenical acid.

20. The seventh and last species of lead ore which I distinguish, is the carbonate of lead. I rank it the last in the order of its native salts, because the carbonic acid is that which adheres with the

the least strength. The carbonate of lead, which is very easy to be distinguished from the other ores of this metal by its solubility in nitric acid, accompanied with very evident effervescence and disengagement of carbonic acid, and by its speedy reduction upon charcoal, was formerly named *spathose lead*, or *white-lead*, because it often has that colour, and because its texture is lamellated, and the varied colours of its plates, are such as characterize what was formerly known by the general name of *spar* in mineralogy: it varies greatly in its form and colour. The laws of its structure have not yet been determined by the researches of Citizen Haüy. By dissection he obtained as a result, sections parallel to the faces of a dodecahedron of two right pyramids, united base to base, with other sections parallel to the faces of a regular hexahedral prism comprehended between two pyramids. He obtained these results from the crystallotomy of the carbonate of lead from Siberia; whereas that from several other places afforded him for the result of their mechanical division, octahedrons: this last form is sometimes found as the secondary form; the secondary form is also in many cases the hexahedral prism with various sections, or facets on the edges of the bases. The prism is seldom terminated by hexahedral pyramids. Carbonate of lead is most commonly found in fine brilliant needles, a kind of irregular striated prisms fluted internally or in stalactites, or incrustations. In part of the strata a portion is found

found, which passes to the state of sulphuret of lead. The colour is no less varied in this species. Some specimens are as transparent as glass; frequently they are semi-transparent, and sometimes they have a dull white opacity; some are yellowish, greenish, and deep green. The latter are often in hexahedral prisms, more or less thick, very regular, and resembling the emerald in form. I have met with some which contained phosphate, no doubt mixed simply with the carbonate of lead. Pelletier has pointed out in the black colour they suddenly assume, by the contact of sulphuret of ammonia, or its vapours when they are reduced into powder, a character proper to distinguish them from the sulphate of barites, with which they are sometimes confounded on account of their form. The carbonate of lead is very abundant among the ores of this metal. It ought, however, to be considered as well as all the preceding salts, as a secondary ore, formed by the alteration of the sulphuret of lead, and transported by water, to which it owes its crystalline form. It is particularly found in Siberia, Saxony, Brîsgaw, Styria, Carinthia, England, and particularly in France, in Poullaouen, Huelget, and Saint Mary-aux-mines, &c.

D. Assays and Metallurgical Operations.

21. THE assay of lead ores is one of the most simple and easy; but as in this operation there

are two objects sought, namely, the lead as the product, and the silver which it almost always contains, and is required to be attended to on account of its price: with this intention, after pounding and washing, a certain quantity of the ore is well sorted, and roasted in a covered test to avoid the loss which decrepitation might produce. It commonly happens that the sulphuret of lead loses but little of its weight by roasting. The quantity of matter volatilized, is determined by accurate weighing after the operation, and comparing this weight with its original quantity; the remainder is fused with twice its weight of black flux, or borax, mixed with a small quantity of charcoal, and a small quantity of decrepitated muriate of soda. The alkali or flux absorbs the sulphur; the carbon reduces the oxidized portion of the metal; and the sea salt, by covering the whole mass, opposes the evaporation. After the fusion, the button of lead which occupies the bottom of the lined crucible, is weighed. When the weight of this is accurately noted, it is put into a cupel, or small hollow vessel formed of calcined bones; a sufficient heat is given under a muffle, to sublime, oxide and vitrify the lead, which in this last state passes through the pores of the cupel, and leaves its cavity very clear. The silver contained in the lead, which is neither volatile nor oxidable, nor vitrifiable like this last metal, remains in the vessel in the form of a small, round

round, brilliant, pure, metallic globule, which is to be weighed with an exact balance.

22. The assay, as it has been here described, is very far from being an exact operation, though it is mostly sufficient to afford the first notions desired respecting the ores of lead, and though it is almost always from the results of this assay that works in the large way are undertaken and conducted, it is necessary to show its defects, because it is not at all difficult to substitute in its place a more accurate and certain analysis. Chemists consider this operation as deceptive, because the alkali usually employed as a flux, forms with the sulphur of the ore, a sulphuret which dissolves a portion of the oxide of lead, and thus deprives the result of part of the metallic product. The inconvenience is less with borax, which I have recommended; but here again the assay is made with an expensive substance, not at all resembling those matters which may be employed in the large way, and it may give false notions with regard to the product to be obtained in this last method: it is therefore, better, instead of this incorrect method, by fusion in the dry way, to adopt the analysis of the lead ores in the humid method.

23. Bergman, in his dissertation on the humid analysis, has given processes, no less simple than exact, for analyzing and distinguishing the different species of lead-ores. If it be found native, nothing more is required than to as-

certain its purity by the nature and proportion of its alloys: for that purpose he advises that it should be dissolved in the nitric acid. If the solvent assumes a green colour, it denotes the presence of copper: the addition of iron will precipitate this metal, and ascertain its quantity. The sulphurets of lead are to be treated by the same nitric acid, which oxidizes and dissolves their metallic portion, and separates the sulphur: this last material must be collected on a filter, dried and weighed. The oxide of lead is precipitated by carbonate of soda, and 132 parts of the precipitate, indicate or contain 100 of lead. If the precipitate be mixed with oxide of silver, ammonia dissolves this without touching the carbonate of lead: 129 parts of this carbonate of silver correspond with 100 parts of the metal. We must here remark that it is often very difficult to separate silver from lead in this manner, on account of the very small quantity; and that if we wish to know the proportion of this precious metal, it is indispensibly necessary to have recourse to the dry way, by reducing and cupelling the lead.

The muriatic acid may be used instead of the nitric, in treating the sulphuret of lead. The muriate of lead is deposited in crystals, which are to be dissolved in distilled water, to separate the sulphur and then precipitate the lead by the carbonate of soda. If the sulphuret contain antimony, this metal remains in a white oxide at the bottom of the nitric acid, or it may be precipitated

precipitated by pure water from the muriatic solution. Though it seldom happens, according to Bergman, that iron should exist in the sulphurets of lead, yet, if it be present, the lead and the silver may be first precipitated from the nitric acid by iron; and by keeping an account of the quantity of this last metal employed for precipitation, it will be easy to ascertain the proportion of that which existed in the sulphuret, after precipitating the whole by an alkaline prussiate. Bergman also remarks, that if there be a small quantity of the matrix, in the lead ore which is analyzed, this will either be insoluble, as flint, and remain unaltered at the bottom of the solvent, or it will be soluble; and in that case the ore must first be treated by the acetic acid which dissolves calcareous matter when present. In the analysis of the sulphurets by the humid way, the proportion of lead is always found greater, and sometimes even a quarter more than that which is obtained by fusion with a flux: a new proof that alkalis dissolve and carry off part of the lead.

24. With regard to the carbonates and phosphates of lead, Bergman is content with pointing out the solubility of the former in the nitric acid; and the treatment of the latter by the same acid which dissolves them; precipitation of the oxide of lead by the sulphuric acid, and evaporation of the supernatant fluid, will leave a residue of phosphoric acid. To this general notion I shall add, that the quantity of carbonic

carbonic acid contained in a carbonate of lead, may be appreciated either by distillation in a retort of stone-ware with a pneumatico-chemical apparatus, or else by collecting this acid in a proper apparatus, in proportion as the ore is dissolved in the nitric or muriatic acids. The phosphates may be treated in an earthen retort, after having mixed them with a fifth or sixth of their weight of charcoal in fine powder. By this means carbonic acid and phosphorus are obtained; and metallic lead remains in the retort. I have already pointed out this process as practicable in the large way with advantage, where the phosphates of lead are found. I shall here add, that such an establishment would be of little expense to the possessors of the mine-works, and that it would bring into the market at a low price, phosphorus, which is actually lost in the treatment of these ores, and is still little used, because being scarce and expensive we are little disposed to treat it, or to apply it in any manner to the necessities of the arts, or of common life.

25. Bergman has not spoken of the molybdate of lead, because it had neither been described, nor was known at the period when he wrote his dissertation. Mr. Klaproth has given very simple processes for analyzing this ore: the muriatic acid decomposes the molybdate, deprives it of the oxide of lead, and separates the molybdic acid in the form of a white powder: this powder, heated by the interior flame of the blow-pipe-

pipe, assumes a blue colour, which renders it easy to be known; it also assumes this colour by the contact of hot sulphuric acid. The quantity is appreciated by dissolving the molybdate in an acid; when the oxide of lead remains in solution, and the molybdic acid separates in a white powder, which is to be washed and weighed. The chromate, so easily distinguished by its poppy-red colour when in the solid mass, and its orange yellow when in powder, may be very accurately analyzed from the experiments of Vauquelin, who discovered it, by the carbonate of pot-ash or soda; carbonate of lead in white powder remains, of which the proportion of principles is known, and the alkaline solution of chromate, which flows above, is afterwards to be precipitated by the muriatic acid, and easily exhibits the quantity of chromic acid. The sulphate of lead is easily analyzed and decomposed by heating it in a close apparatus with charcoal: it affords sulphureous acid, sulphurated hydrogen gas, and reduced lead. Hence we see that nothing further is to be wished for respecting the analysis of lead ores.

26. The treatment of the ores of lead in the large way is one of the most important of metallurgical operations, and one of those which have the greatest, as well as most intimate relation with the knowledge and accurate processes of chemistry. At Pompéan they work a sulphureous ore of lead, containing silver, by pounding it

in the stamping engine, carefully washing it on platforms, carrying it to the blast-furnace; where it is first roasted by a gentle heat, and afterwards fused by increase of temperature. The fused lead is drawn off from the furnace by opening a hole on one of the sides of its hearth, which during the fusion was kept closed with loam. The lead is first cast into pigs, which are called work-lead, because it is intended to be used in subsequent operations to separate the silver which it contains. This last process, which is the most important part, is generally executed as follows: The lead is carried into a furnace different from the former, the bottom or hearth of which is covered with ashes well washed, sifted and rammed down. At one of the sides of this hearth it receives the twines of two large bellows placed without the furnace, moved by water, and opposite these twines at the other side of the furnace, two gutters are made for the passage of the litharge. The heated lead in fusion becomes oxidized at its surface particularly, by means of the abundant and compressed air which the bellows pour over it. Part of this oxide evaporates by small chimneys, which are opened above the passage of the litharge; another portion is absorbed by the pulverulent bottom of the furnace; but the most considerable quantity of this oxide, being strongly burned and vitrified, and afterwards cooled and condensed by the air which immediately strikes it, is driven by the action of this air towards the
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the channels opened opposite the twires. This last portion is called litharge ; it either has the form of small reddish scales, brilliant and vitrified, and is then called merchantable litharge, and is preferred to the darker coloured litharge, called litharge of gold. That portion which has undergone the strongest heat is most advanced in its vitrification, and of which the colour is pale yellow, is distinguished by the name of litharge of silver, *Argyrites* ; lastly, at the moment when the furnace is most strongly heated, this oxide being more completely melted, flows in the form of drops or stalactites, and is called chilled litharge. When all the lead is thus oxidized and vitrified, the silver remains alone and pure at the bottom of the furnace. It requires, as I shall observe in the history of this precious metal, to be refined in order to extract a small portion of lead which still remains in it. The lead, oxidized by this operation, is then taken and fused amidst charcoal in a large furnace, where it becomes reduced, yielding its oxygen to the ignited coal, and appears again in the form of metallic lead at the bottom of the furnace ; it is then cast into pigs and sold. The other ores of lead which are not the sulphurets, and do not, like them, contain silver, are treated by reduction and fusion in charcoal ; and the phosphates, by this method of decomposition, exhibit the phosphoric flame, which rises above the furnaces, and is easily distinguished by its colour and its odour.

E. Oxida-

E. Oxidability by the Air and by Fire.

27. LEAD exposed to the air becomes speedily tarnished, soon loses the slight brilliancy which characterizes it, becomes of a dirty grey colour, and afterwards of a light grey, which constitutes a true rust at its surface. It is soon perceived that it is more changeable by cold air than tin; for while this last metal exhibits only a very superficial stratum, a slight tarnish which always leaves its metallic colour apparent, the other metal exhibits a deeper oxidation, and becomes covered with a thick stratum of oxide that gradually increases and rises up in a kind of scales from the lead which it covers, and at length penetrates through the whole mass of lead when the thickness is but slight. Nevertheless, the maximum of its alteration is long in taking place, and the internal part of the sheets of this metal is long defended by the slight stratum of oxide which is produced at its surface. Alchemists have pretended that by long exposure to the air lead is changed into silver. This error arises from the lead, employed four or five hundred years ago in the covering of buildings not having been well purified, and the silver which was left resisting the air, while the lead was gradually destroyed, deceived them because they were not acquainted with the primitive nature of this silver-bearing lead.

28. When

28. When lead is fused in contact with the atmosphere, a pellicle of many colours is formed at its surface, of which the golden yellow shade predominates over the others, and soon gives place to a uniform deep grey. If this first pellicle be taken off, which does not adhere to the metal beneath, a second is formed, and in this manner the whole of any given quantity of lead may be converted into pellicles by renewing the surface exposed to the air. These pellicles being afterwards heated and agitated in contact with the atmosphere, become converted into a greyish powder, often mixed with yellow or slightly greenish particles. This is the grey oxide of lead, or the first state of oxidation, which this metal is capable of sustaining. It is easy to reduce, though not spontaneously or alone, but by the assistance of hydrogen and carbon, at the temperature of ignition.

29. We must remark, that if lead be heated much above the temperature necessary to fuse it, and to produce the simple oxidation I have mentioned, it rises in vapour in the air, and burns more rapidly, emits a white or yellowish fume, of a peculiar smell, which becomes condensed in a grey yellow oxide upon cold bodies, and which some authors have denominated flowers of lead. This volatilization of fused lead, and the oxidation it undergoes in the air, are the causes of the dangerous effects it produces on those who work on this metal, or are exposed to its vapors. The mere powder of lead, and its oxides, transported by the
air,

air, either by working the lead itself, by scraping or filing it, under different circumstances in which its oxide becomes diffused in the atmosphere, even with other vapours, such as that of volatile oils, produces the same affections in those who receive it by the mouth, by the lungs, or by the skin.

30. The grey oxide of lead, when strongly, and for a continuance of time, heated with the contact of air, soon becomes yellow by a new absorption of oxygen. In this state of yellow oxide it is called *massicot* in the arts; it appears that it contains from six to nine parts of oxygen in the hundred parts. It is distinguished into two kinds, in commerce, on account of its colour; the one is called *white massicot*, and the other *yellow massicot*. It is a pigment of a dull hue, without any beauty, sometimes inclining to green, which nevertheless is prepared in the large way in certain manufactories, on account of the uses to which it is applied in the arts. The method of producing it consists simply in perpetually agitating the lead with the contact of the air, without using a violent heat, which would afford another result presently to be mentioned. The yellow oxide of lead is produced with much greater success in the large way than in the small operations of the chemical laboratories.

31. There is a third state of the oxidation of lead, namely, that in which it assumes a beautiful fiery red, more or less inclined to orange, which is called *minium* in the arts, and the

the red oxide of lead in the methodical nomenclature. Whenever lead is heated for a long time in laboratories without using a heat capable of vitrifying the grey oxide of lead, it becomes totally changed into a red powder; but the oxide is never by this treatment rendered entirely red, nor of a fine colour: it is even a sort of secret or delicate operation which demands a careful and experienced manipulation, which is known in the preparation of this oxide in certain manufactories. Some years ago, the red oxide of lead was fabricated only in England and in Holland; at present there are several establishments in France, where this preparation is made equal in beauty to that from foreign countries. In a kind of reverberatory furnace in which lead is melted, the heat is urged till the mass becomes a cherry-red colour. The lead is perpetually agitated, by drawing the oxidized part towards the sides, and the quantity of air necessary to this oxidation is suffered to enter by the openings, which serve to admit wood or coal. The first oxidation lasts four or five hours. By leaving it for twenty-four hours, drawing it out of the furnace, and suffering it to cool in the air, and by throwing a small quantity of water upon it, and stirring it up, the true massicot is obtained, according to the description given by Jars, in the Memoirs of the French Academy for 1770, which is afterwards ground in a mill and diffused in water, in order to have a fine powder of equal quality. This yellow

low oxide or massicot being again treated in the reverberatory furnace for thirty-six hours, affords a red oxide or minium, after having been exposed in an elevated mass, flattened at the top, and opened cross-wise. It appears that the art of manufacturing this last oxide, particularly that of obtaining a fine brilliant red colour, consists in leaving it when at the cherry-red heat, in the furnace to cool very slowly, by closing all the apertures very carefully, and that this practice has for its object, that the oxide shall receive only a certain dose of oxygen; for I have seen, in a valuable manufactory at Paris, this oxide taken very hot out of the furnace of a very rich red colour, become singularly pale in the air, and of a brownish or almost fawn-colour, not at all brilliant, whereas it preserves its orange shade, when it was suffered to cool in the furnace hermetically closed.

32. The red oxide of lead varies more or less in its colour from the very bright light orange, so much extolled in some of the arts, to the almost deep cherry-red. There are as great a variety of shades as manufactories. It is commonly estimated that this oxide increases in weight ten per cent. and that in this manner one hundred parts of lead afford one hundred and ten of minium. Nevertheless authors vary respecting the quantity of this augmentation of lead. Some admit fifteen per cent. others carry it to twenty per cent. Wallerius and Wafferberg have adopted this last datum after their own observations

servations and experiments. However, though this augmentation appears to be so much the greater, as the operation has been more perfectly made, and particularly the slower it is performed, it is acknowledged after the last experiments of Citizen Vauquelin, that the most constant proportion of oxygen in red lead is nine parts in the hundred. This oxide is partly reducible in a retort, and affords a small quantity of oxygen gas; but there is not the slightest portion which passes to the metallic state; it is very probable that this portion is not in the same state as the rest of the oxide: it may be reduced completely by various methods which I shall proceed to describe.

33. The yellow oxide, and the red oxide of lead, strongly heated, flow and become vitrified with great facility. Of all the metallic oxides these undergo this remarkable change most speedily and with the most energy. It is probable that the glass of lead is still more oxidized than the red lead, since this last, when exposed hot to the air, changes its colour, passes to the same yellow colour it has when it has been vitrified. This vitreous oxide is at the same time the strongest flux and the most powerful vitrifier that we are acquainted with. No vessel can resist it; it passes through them all in the same manner as water passes through paper. Pott remarked, that this fused glass cannot be kept for more than three quarters of an hour in the most solid and most refractory crucible; and

Macquer

Macquer observed on this subject, that it is impossible for this reason to have the glass of lead in a very pure state. Chemists have used great endeavours to discover compositions of earth capable of resisting it; and though they have not resolved this kind of problem, because there is no earth which is capable of obstinately resisting the oxide, they have nevertheless approached considerably to the solution of their question. Hard porcelain which has been strongly baked, such as that of Sevres, is the substance, which at the same time that it resists the most, is the most difficultly acted upon or perforated by this violent and powerful flux.

34. The oxidation of lead has in all times been one of those phenomena, which, on account of the augmentation of weight in the metal has strongly occupied the meditations of chemists, philosophers, and physicians. Its history is in a certain degree connected with the advancement and progress of the human mind. After the fruitless attempts of Cardan, Scaliger, and a number of men of great merit, to explain it, John Rey was the first who suspected the cause, though for more than a century and a half after him, and notwithstanding the ingenious machines of natural philosophy, constructed since the middle of the seventeenth century, to the two first third portions of the eighteenth, it still escaped the research and the sagacity of Newton, Boyle, Mayow, Hales, Stahl, Boerhaave, and all the philosophers. It

was

was reserved for Lavoisier, as we have seen, to convert the suspicion of John Rey into certainty with regard to the oxidation of lead, and to prove that this augmentation of weight is owing to the principle of the air which is fixed in the metal. Hence, therefore, arises that increase of weight in the lead by means of the air, which has become one of the first and most beautiful facts of the pneumatic doctrine, and one of those which has served to establish the first foundation of that theory.

F. Union with Combustibles.

35. LEAD combines with most combustible substances: but we are not acquainted with any combination with azote, hydrogen, and carbon. These two last bodies act on its oxides by heat, so as to reduce them by depriving them of oxygen. Water and carbonic acid are formed; the oxide repasses to the metallic state. The reduction is effected in the cold in the course of time, by the contact of hydrogen gas. It must be noted that there is no metallic oxide more easily and more completely reducible than those of lead; which shows the slight adherence of this metal with oxygen.

36. The union of lead with phosphorus, has been examined by Pelletier: he obtained it either by throwing phosphorus upon lead fused in a crucible, or by distilling phosphorus with

lead in a retort. The phosphuret of lead is of a bluish silvery white; it is capable of being cut with a knife. Its structure is lamellated; and when it is struck upon the steel, it separates into plates. Above it in the crucible, wherein it is prepared, is found a white milky glass formed by the union of the phosphoric acid and the oxide of lead. The phosphuret of lead speedily tarnishes in the air. When heated with the blow-pipe, the phosphorus burns at the surface of the button, which speedily fuses, and the lead does not become oxidized but very slowly. The fusion obtained in a crucible, is incomplete and passy, so that it is somewhat less fusible than the two bodies which compose it are separately. During this fusion, a small quantity of phosphorus is always disengaged, which burns at the surface with the flame, the white smoke and the odour, which characterize that substance. The phosphorus, according to Pelletier, is contained in the proportion of from 0,12, to 0,15.

37. Sulphur readily unites with lead. This combination was not unknown to the ancients, since it is described in Dioscorides. It has long been called burned-lead, *plumbum ustum*. Dioscorides prepared it by stratifying plates of lead in an earthen vessel with sulphur, setting this on fire, and afterwards agitating the whole with an iron rod. From this operation the result must be either a sulphate or sulphite of lead. The true artificial, sulphuret of lead is formed

formed either by heating lead and sulphur mixed together in a crucible, or by throwing sulphur upon melted lead in the same vessel. In either operation the product is a black, brilliant substance, much more difficult to fuse than lead and sulphur separately, having a fibrous or filamentous striated texture within, very brittle, and resembling in a certain degree in its colour the native sulphuret of this metal, or galena. Juncker and Wallerius advised five parts of granulated lead, and two parts of sulphur in powder, to be taken for this compound. Citizen Baumé prescribes two or three parts of lead, and one of sulphur: this factitious sulphuret has absolutely the same habitudes as the natural sulphuret with chemical agents.

38. The union of the oxides of lead with sulphur is not known; their existence is even doubted, because when these two bodies are heated together, the oxide seems to be reduced, and approach to the metallic state, and the sulphur seizes its oxygen; so that it soon forms a compound, which is a true sulphuret of lead; because the same reduction takes place when sulphurated hydrogen gas, and a white, yellow, or red oxide of lead, are put into contact. These oxides immediately become dark-coloured, and the water charged with sulphurated oxygen loses its smell and properties. From this very powerful action I have admitted the use of the oxide of red lead to decompose sulphureous waters, and to ascertain the quantity of sulphu-

rated hydrogen they contain, by the examination of the sulphuret, or perhaps the hidro-sulphuret of lead which they afford with this oxide.

39. Lead is capable of uniting with a great number of metallic substances. Juncker is content to say, that lead heated with the oxide of arsenic is partly volatilized and partly fused into a glass of the colour of hyacinth. Wallerius, who also speaks of the hyacinth-coloured vitrification in a like combination made with metallic arsenic, adds, that part of the lead retains the metallic form, but becomes brittle and shining in its fracture, and that the vitrified oxide of lead, assumes, when fused with the oxide of arsenic, a red colour. These facts which seem to have been forgotten by most of the modern systematical writers, in whose works we find that no union takes place between those two metals, prove nevertheless that arsenic really combines with lead; that the result of this combination is a lamellated and brittle alloy; that the lead shares with the oxide of arsenic part of its oxygen; and that when these two oxidized metals are united by vitrification, there also is established between them an equilibrium of oxidation of which I have already spoken several times; and which changes the colour with all the other properties. The theory of science ought to consider this effect which presents a great number of applications to the arts of glass-making, enamelling, making of porcelain, and the preparation of colours.



40. The

40. The combination of lead with tungsten, molybdena, chrome, titanium, uranium, and manganese, have not yet been treated of. These metals, still so new and so little known as to their relation with the other metals, most of them being so difficult to treat, and particularly having been hitherto obtained by chemists in so small a quantity, have scarcely at all been alloyed together, or with those which preceded their discovery. It is nevertheless of great use in the proper study of metals to examine their various alloys, because it has already been shown that one of the principal means of ascertaining their differences, and determining their specific characters consists in their union with other metallic matters. In the still scanty number of facts collected respecting their alloys, few attempts have been made to alloy them with lead, because no expectations of utility were built upon the probable result of this combination.

41. According to Gellert, cobalt has but little attraction for lead. When these two metals are melted together in equal proportions in a crucible, the cold mass is found to be separated into two portions; the one which is heavier occupying the lower space, and the other, which is lighter, being placed uppermost, and slightly adhering to the former. It might therefore be imagined that there is no union between these two metals: nevertheless when cobalt is treated by fusion with lead, and then
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with iron, which has a stronger attraction for it, a small portion of lead is separated at the bottom of the crucible, which proves that the cobalt had taken a portion in the first fusion. Citizen Baumé affirms, that he did not find lead in cobalt treated with that metal. This last, according to him, does not deprive cobalt of sulphur: when equal parts of sulphuret of cobalt and of lead are cupelled, the former remained in the form of black powder on the cupel, which the pure colourless glass of lead had penetrated. Wallerius also affirms, that those two metals contract no union together.

42. Cronstedt found that nickel united but with difficulty to lead, and that the result was an alloy of a dirty grey colour, with little brilliancy, lamellated and brittle. Wäasserberg, on this head, reproaches Citizen Baumé for having affirmed that Cronstedt had asserted nothing of this kind respecting these two metals in the metallic state, and that he had spoken only of their mutual vitrification. But an examination of the writings of Citizen Baumé, and the comparative history of the progress of science among those who have cultivated it for the last forty years, would have easily shewn him that the French chemist has scarcely ever spoken but from his own experiments; that he every where boasts of having done more than he, and on this head there is no doubt that every thing which he did not or could not do, was considered by him as not done. It is however certain, as Wäasserberg relates,

lates, that Cronstedt, in his examination of nickel has positively affirmed, that it unites to all the metals except mercury and silver.

43. Muschenbroeck made experiments at some length, on the alloy of lead with bismuth. He observed, that the latter gives to lead a remarkable degree of firmness and tenacity when the two metals are in equal quantity: a given mass of this alloy in equal parts, supported a weight of 207 pounds; a like mass of the alloy of three parts of lead and two of bismuth, supported 290; that of three parts of bismuth and two of lead 147. He concluded that bismuth appeared to act as a gluten in the lead, of which it causes the parts to adhere more strongly. Gellert found in this alloy a greater specific gravity than the mean derived from the specific gravities of the two separate metals. Wallerius describes it as of a dark grey colour, rather ductile in equal parts; and he observes, that the bismuth separates during its union with the lead in more abundance in scoria, even than when lead is mixed with tin. Citizen Baumé obtained from equal parts of bismuth and lead, a metal harder than the lead, considerably malleable, and resembling the purest steel in its colour. One part of lead and two of bismuth afforded him a more brittle harder alloy, coarsened in its texture, and whiter than the foregoing. Two parts of lead alloyed with six parts of bismuth, and half a part of antimony, afforded him a very hard metal, nor at all compressible

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by the hammer, formed of small close grains, and of a silvery whiteness.

44. The same authors have examined the alloy of lead and of antimony. Muschenbroeck found this alloy to be very tenacious, when the lead was united to one eighth part of its weight of antimony. A mass of this alloy supported a weight of 260 pounds, while a like mass of lead or of antimony would not have supported more than thirty. When united in equal parts, the tenacity is very little, and the mixture is brittle. Muschenbroeck concludes from this property, that nature observes, or rather has established, a minimum and maximum, or constant limits: Gellert ascertained that this alloy has a greater specific gravity than that afforded by the proportion of the two metals united. Wallerius has announced, that when composed of equal parts, its colour is dull and it is brittle; Citizen Baumé affirms, that it has brilliant facets, and he has also described other alloys in different doses. Two parts of lead with one part of antimony, afforded him a brittle tarnished metal in small grains, similar to those of iron; four parts of lead and one of antimony, an alloy rather more ductile and coarse grained; four parts of lead with half a part of antimony, a soft metal, very fine grained, like steel, and of the same colour. Lead has besides, like many other metals, if we except gold and platina, the property of separating sulphur from antimony, and decomposing its sulphuret: the antimony thus obtained, retains a small portion of lead.

45. Mercury

45. Mercury unites with lead with much facility, and in all proportions. Mere trituration of mercury with lead in raspings, is sufficient to form the combination. If the mercury be heated and poured upon melted lead, the combination succeeds still better. In this manner, an amalgam is obtained, which varies in its solidity according to the proportion of the two alloyed metals. It is white, changeable by the contact of air, affords crystals by well-managed cooling, loses the mercury by a strong heat, and suffers a blackish powder of oxide of lead to separate, when it is ground with water; it has the singular property of becoming very liquid, when triturated with the amalgam of bismuth. This phenomenon induced Citizen Baumé to make inquiries respecting the sophistication of mercury. After having melted in an iron vessel equal parts of lead and bismuth, running mercury was added, with heat, in a sufficient quantity to amount to the half of the whole mass. This mixture was agitated till it cooled; by this means a fluid amalgam was obtained, which did not congeal by the air or by repose, and passed almost entirely through leather like mercury alone. A part of the bismuth separates in grey powder at the surface of the mercury; but the lead remains intimately combined. The phenomenon of this liquidity is not so difficult to be understood as Citizen Baumé imagined; it depends on the lead, the bismuth, and the mercury, acquiring in their mutual

mutual combination a greater capacity for caloric, than they had separately or united two and two; in consequence of which they absorb more of this principle; and remain in a state of liquidity, which they would not have assumed in their separate state. This sophistication of mercury may be ascertained by the less specific gravity of the alloy compared with pure mercury; and also because, when the mercury is made to run in a small quantity over a plate of earthen ware, each globule leaves a tail behind it, and has a flat appearance, instead of being round or spherical. When the mercury of this amalgam is carried off by the action of heat, the lead remains in the form of a yellowish oxide, which can no longer continue united with the liquid metal. Many chemists affirm, that mercury, exposed in a piece of linen to the vapour of fused lead, becomes solid, or fixes: the most accurate experiments have merely shown that it loses part of its fluidity.

46. Wallerius has described the properties of the alloy of lead with zinc in equal parts of each. According to him, this alloy is harder than lead, whiter, and perceptibly malleable. The lead is rendered volatile by the zinc, when ten or twelve parts of the latter are united with one-third part of the former; but if the zinc be less abundant, it separates from the lead. Some authors affirm also that balls are made with lead and zinc, which never vary from the direction communicated to them, and therefore strike

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more directly the butt towards which they are fired ; but they do not give the proportions of this particular alloy. Gellert has pointed out the alloy of lead and zinc as specifically heavier than the mean weight of the two metals as ascertained by calculation. Muschenbroeck, after many experiments of alloys of lead with zinc, found that the metal has a very strong tenacity, and the greatest possible degree of hardness, when eight parts of the former are united with one of the latter. The experiments of Citizen Baumé seem to contradict all the facts announced by those authors ; since, according to this artist, equal parts of zinc and lead melted in a crucible did not unite ; the lead remained above the zinc without any change. He had the same result when he melted two parts of lead with one of zinc.

47. Lead unites with tin in all proportions. Muschenbroeck, who made many experiments on this kind of alloy in a great number of proportions, remarked, that lead adds much to the firmness and hardness of tin ; that a metal formed of three or four parts of tin, and one part of lead was twice as hard as pure tin, and that the best proportion to carry the tenacity of tin as fast as possible, consists of three parts of the latter to one of lead. Thus it is, according to him, that the lead used to transport tea from China to Europe contains a small quantity of tin, which hardens it ; but it must be observed, that zinc, or bismuth, enters into this
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Chinese alloy. One-fourth part of tin, alloyed with lead, prevents it from vitrifying and penetrating the cupel, according to Juncker: this alloy, treated by cupellation, swells up, rises in vegetation, becomes strongly ignited, takes fire, and soon leaves on the cupel a hard granulated oxide, very difficult to be fused. Two parts of lead, and one part of tin, form a more fusible alloy than the two metals, and do not separate. It is common solder, or the solder of the plumbers.

48. The alloy of lead and tin is very frequently employed in the ordinary uses of life, and the former of these metals renders the use of this alloy very dangerous in vessels for culinary use, or for pharmacy; whence it becomes of great importance that we be able to ascertain the respective proportions of tin and of lead, the latter being very frequently carried beyond the proportion by the wise regulation of the police. The pewterers have several processes to ascertain this degree of fineness in the tin, and consequently the quantity of lead it contains; they frequently depend upon simple inspection; the colour, the weight, and the noise afforded by this metal when bended, are sufficient for men of experience to form a judgment of the various alloys of tin. They also practise in France two different kinds of assays: the one, named assay by the stone, is made by pouring melted tin into a hemispherical cavity, terminating in a hollowed channel in a thunder-stone, a kind of
hard

hard carbonate of lime of a fine grain: The phenomena which the tin exhibits in its cooling, colour, roundness, the depression of its middle, the noise it gives when the tail of the tin is bended, are signs which the intelligent pewterer avails himself of, and which by long observation indicates to him with considerable accuracy the fineness of the tin he examines. This assay is however much less exact and certain than that which is called the assay by the ball or the medal, which is practised in the provinces, whereas the former is used at Paris. This assay may indeed show somewhat less of skill or experience in its use than the assay by the stone, but it has at least the advantage of affording a more accurate knowledge than that process can do. The assay by the ball consists in pouring the tin, of which the quality is to be estimated, into a mould which gives the form of a ball, or of a flat piece resembling a medal. The weight of this cast is then prepared with a like volume of fine tin cast in the same mould. The more the cast exceeds that of the pure metal, the more it is estimated to be alloyed with tin. It is evident that it would answer much better to take the specific gravity exactly in the manner of philosophers; and that even with this precaution we should have only a general and imperfect notion of the purity of tin, without determining any thing respecting its nature and its alloy, because several causes not relating to the

the proportion of the two metals may influence the specific gravity of the alloy.

49. Chemical analysis alone is sufficient to afford a positive knowledge respecting the proportions of an alloy of lead and of tin. Bayen and Charlard have given a process no less excellent than simple, and easy to be carried into execution for this purpose. They propose to treat one hundred parts of the tin in question with near three hundred parts of very pure nitric acid, to wash the oxide of tin afforded thus, in more than thirty times its weight of distilled water, and to evaporate this water mixed with the nitric acid first decanted from above the oxide. This fluid affords nitrate of lead, if that metal was contained in the tin which is examined: this salt is calcined, and the oxide of lead being weighed, is estimated to represent the quantity of that metal existing in the alloy, deducting six or eight hundred parts at most for the quantity of oxygen which the lead has absorbed from the nitric acid. Having employed this very excellent process on different specimens of wrought tin, they ascertained that the dearest and best in the market contains about 0,10 of lead; and that common tin contains 0,25. This last quantity of lead in tin must produce the greatest danger to those who employ utensils of this metal; and it is unfortunately used in the vessels of most common application, such as the measures for liquids, particularly wine.

wine. It is an object which deserves the attention of an enlightened government.

50. The most singular and most remarkable perhaps of all the alloys of which lead constitutes a part, is that which has long been known by the name of the fusible alloy, on account of its astonishing fusibility. When eight parts of bismuth, five parts of lead, and three of tin, are fused together, this alloy, as Citizen Darcet has discovered, has the property of melting, or rather of remaining liquid at the temperature of boiling water; so that when it is plunged in this liquid, at eighty degrees of Reaumur, it melts at the bottom of the vessel which contains it. This alloy crystallizes by slow cooling, and may become extremely useful in the arts.

G. Action upon Water and the Acids.

51. WATER has no immediate action upon lead, which does not separate its oxygen, nor decompose it; but if the water contain air, or the two bodies be at the same time exposed to the air, the lead becomes speedily and easily oxidized. By agitating this metal in a small quantity of water with contact of air, as Mr. Luzuriaga has done in his experiments on this subject, it soon becomes covered with a white crust of oxide. This is the cause of the white line, which is formed in reservoirs of lead at the edge of the water, or at the point where the metal touches the
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the water and the air. But this effect soon becomes complicated; the oxidized lead absorbs the atmospherical carbonic acid; carbonate of lead is formed, which is even dissolved in the water, as is proved, by pouring hydrosulphurets into this water; which, by such addition, assumes a black colour. There is particular opportunity to make this observation in cisterns which serve for chemical experiments, and there is no reason to doubt but the same phenomenon takes place in all the leaden reservoirs in which water is preserved, since they all show this white projecting border, which is as it were swelled out at the place to which the water rises in those vessels. We see, therefore, that channels, and particularly reservoirs in which water remains, are very dangerous for the common purposes of life, and were condemned in ancient times by Hippocrates, Galen, and Vitruvius; in addition to which, we may depend on the observations of Van Swieten, Tronchin, and Percival, who have quoted unhappy examples of whole families poisoned with water which had remained in reservoirs of lead. The oxides of lead are not soluble in pure water; but if this water be slightly assisted by some saline bodies or alkalis, or by acids, it becomes more or less abundantly charged with it.

52. There is no action between lead and the metallic oxides. This metal has too slight an attraction for oxygen to decompose them; it merely shares, in some instances, the oxygen with the
other

other metallic oxides, and puts itself into an equilibrium of oxidation. This happens very frequently in preparations of enamels and coloured glasses. Most of the metals, on the contrary, have the property of decomposing the oxides of lead, depriving them of oxygen, and reducing them to the metallic state, or at least bring them near that state.

H. *Action of Acids.*

53. LEAD is acted upon by the acids in a very different manner from tin. It is much less oxidized by their action; it combines much better with the acids in general, and forms permanent solutions. The sulphuric acid does not act upon lead in the cold, nor even at a temperature which causes the acid to boil. For this reason lead is used to line the chambers in which sulphur is burned in the fabrication of the sulphuric acid. This metal is very little altered, by the contact of the acid in vapour, and it lasts a long time. When concentrated sulphuric acid is heated upon filings of lead by ebullition, an effervescence takes place, and sulphureous acid gas is disengaged; the lead appears to be changed into a thick white sulphate, which remains at the bottom of the fluid, when in great abundance, or is obtained dry if the acid has been employed only in sufficient quantity to act upon the lead. By washing this last mass in distilled

water, the water dissolves only a small portion of sulphate of lead by virtue of a minute excess of sulphuric acid. This washing affords small needles by evaporation. Citizen Monnet affirms that the sulphate of lead is obtained in short prisms. Citizen Sage has described it in tetrahedral prisms: it is to be observed that this salt cannot be dissolved and crystallized, but by virtue of an excess of acid, for which reason it is that several chemists have denied its existence. Water in whatever quantity it may be employed, will never, unless sulphuric acid be added, dissolve the whole of the white mass of sulphate of lead, for which reason the salt is generally considered as insoluble, incrySTALLIZABLE, and little disposed to decomposition. It is scarcely alterable even by a strong fire, and cannot be decomposed but with charcoal. When heated alone, it never affords sulphur, but merely sulphureous acid. The alkaline earths and alkalis decompose it, and separate the oxide of lead in a pure state by absorbing the sulphuric acid. The oxide contained in the sulphate of lead appears to contain 0,07 of oxygen; one hundred and forty-two parts of this salt represent a hundred parts of the metal, which is very important to be known for assays, and the various inquiries relating to the combinations and different states of the oxidation of lead.

54. Lead does not act on the sulphureous acid, and it is known from what has been said, that it is not dissolved.

lated, that in fact this metal disengages only sulphureous acid, and never sulphur from the sulphuric acid. The sulphureous acid cannot therefore dissolve lead; but it easily unites with its oxide, and forms sulphite of lead with it, provided it be not too much oxygenated. The following are the facts which this combination presented to Vauquelin and myself, in our united inquiries respecting the combinations of that acid with the metals. The red oxide of lead put into contact with the liquid sulphureous acid soon becomes white; the acid loses its smell, and a saline mass is formed, containing a mixture of sulphate, and a sulphite of lead. The sulphite cannot be obtained alone, but by treating the white oxide of lead separated from the nitrate of this metal by the sulphureous acid. The sulphite thus prepared is insipid and insoluble. Before the blow-pipe on charcoal it melts, emits a slight phosphoric flame, and becomes of a pale yellow in cooling. When heated for a long time it becomes reduced at its edges, after which it boils, and passes to the metallic state. In a close vessel it affords water, sulphureous acid, sulphur, and leaves the sulphate of lead of a greenish yellow. The sulphuric and muriatic acids disengage the sulphureous acid with effervescence; the nitric acid does not decompose it: which ought to happen, since the sulphureous acid takes on the other hand the oxide of lead from the nitric acid; but it changes it into sulphate, and disengages a red vapour.

vapour. The alkalis deprive it of its sulphureous acid. If, instead of treating red oxide by the sulphureous acid, it be treated with the fulphite of soda at the temperature of ignition, the oxide passes to the state of metal, and the fulphite of soda becomes sulphate but with excess of soda, because the sulphuric acid thus formed saturates less soda than sulphureous acid. All this proves that the red oxide of lead yields a portion of oxygen to the sulphureous acid alone, and all its oxygen to this acid when united with pot-ash and soda.

55. The nitric acid, somewhat diluted with water, acts well upon lead; the acid dissolves it entirely with a continued and equal effervescence. If it be too strong, it leaves the oxide dry: but this oxide is equally soluble in weak nitric acid. The solution is not rendered turbid by water. Its taste is first sweet, afterwards rough and acrid. It separates during the solution a grey insoluble powder, which Groffe supposed to be mercury, but which does not really contain it, and of which the nature has not yet been determined. By direct evaporation of this solution, it afterwards affords by cooling, regular crystals in the form of flat triangles, of which the angles are truncated; by slow and spontaneous evaporation, hexahedral pyramids are obtained, truncated at three faces, alternately broad and narrow, which considerably resemble a three-cornered hat, and have been well described by Rouelle. These crystals crackle and decrepitate

decrepitate strongly on hot coals, at the same time that they throw out very brilliant sparkles. Boerhaave affirms that this decrepitation, which is dangerous to the by-standers, has caused the salt to be denominated fulminating lead. After this effect, a yellow or reddish oxide of lead remains, which is reduced into metal upon charcoal. In a closed vessel it affords nitrous gas, oxygen gas, azote gas, and the oxide of lead becomes vitrified. The solution of nitrate of lead precipitates a white oxide by the alkalis, and a black sulphurated oxide by the sulphurets and hidro-sulphurets. The sulphuric acid and the sulphates decompose it, and form a white precipitate of sulphate of lead, which is thick and insoluble. The sulphureous acid also precipitates it in the form of fulphite of lead.

56. The action of nitric acid upon the different oxides of lead deserves to be carefully ascertained. Before the experiments of Proust and Citizen Vauquelin, nothing was known further than that these oxides are soluble in the acid of nitre. It is now known that the difference of the oxides makes a difference in the action of the acid. The white oxide and the yellow oxide are dissolved quietly without effervescence, without residue, and without any perceptible change either in their nature; or in that of the acid: but the case is very different with the red oxide. When the nitric acid, at twenty-six or thirty degrees, is poured upon this, heat is extricated, the oxide becomes white,

is in great part dissolved, and at the same time a portion of black insoluble powder is separated. This powder being well washed, collected, and dried, weighs 0,15 of the oxide employed. When it is examined, it is found to be a brown oxide of lead, deeper coloured than all those before spoken of, the most oxygenated of all the oxides; it is also obtained more easily and abundantly by the oxygenated muriatic acid, as I shall soon explain. It is only necessary to explain, in this place, what happens in the action of the nitric acid. About six-sevenths of the red oxide are soluble in this acid; but as their state of oxidation, at 0,09 of oxygen, does not allow them to dissolve, in proportion as the excess of this principle is separated, it acts upon the other seventh part which remains insoluble, and becomes brown; so that the dis-oxidation of the six-sevenths, and the super-oxidation of the seventh, are the product of the double attraction of the nitric acid for the white oxide and the red oxide for the portion of oxygen proper to convert it to the state of brown oxide. Hence we see why the white and yellow oxide are soluble in the nitric acid without forming the brown oxide.

57. The muriatic acid acts, though weakly, upon lead, and its oxide, when these two bodies are heated. One part of this oxide remains in the liquor; another part combines with it. This last is not abundant, and is only dissolved by means of the excess of acid; it affords brilliant
prismatic

prismatic crystals of a satin-like appearance in fine needles of muriate of lead. This salt is not deliquescent; it dissolves in water; its taste is sweet, but harsh; it is decomposed by the alkalis, which precipitate a white oxide. These two bodies are more directly united, and better saturated with each other, by presenting an oxide of lead to the muriatic acid, or by pouring this acid either at liberty, or engaged with some alkaline or earthy basis, into the solution of nitrate of lead. A white thick precipitate is immediately formed, having the appearance of a heavy coagulum much more abundant than the sulphuric acid forms, which is speedily collected at the bottom of the fluid. The muriatic acid has therefore a stronger attraction for the oxide of lead than the nitric acid has. The muriate of lead thus formed has a sweetish taste; it is soluble in thirty times its weight of water; it melts very easily by heat, and emits when fused a white vapour, which, if received in the mouth, leaves for a long time a saccharine taste, and condenses in white crystalline powder upon cold bodies. When this salt has been fused, it is a semi-vitreous brilliant mass of a deep grey or brown colour, called corneous lead, either because it has a shade of colour similar enough to certain horns, or because it resembles the muriate of silver, which after similar fusion was called horn-silver. When the muriate of lead has been dissolved in water, prismatic, sub-hexahedral and striated crystals are obtained by evaporation.

ration. The sulphuric acid, according to the remark of Groffe, precipitates this solution in an insoluble sulphate of lead. In other respects, its habitudes resemble the other salts of lead with alkaline and sulphurated re-agents.

58. When the red oxide of lead is slightly heated with muriatic acid, the acid in part becomes oxygenated muriatic acid, while the oxide being difoxygenated, unites to another portion of the acid, and produces muriate of lead in the form of a white powder: an excess of the acid redissolves the muriate. The muriatic acid cannot, therefore, unite with the red oxide of lead without difoxygenating it, and bringing it to the state of the white oxide. On this account it is that lead treated by this gas, or the liquid oxygenated muriatic acid, passes only to the state of white oxide, and then unites with the muriatic acid difoxygenated by the oxidation of the metal. Citizen Fabroni has proposed to prepare in this manner, the oxygenated muriatic acid for bleaching prints upon paper. This acid is not afforded by the process here described, unless a small portion only of the red oxide of lead be used, and when the acid is sufficient to saturate this oxide; for if the dose be augmented, the muriate of lead becomes charged with a portion of brown oxide. These effects (a) show that the muriatic acid cannot unite but with the white oxide of lead, and that it difoxides the red oxide before it can combine with it; (b) that this acid has a stronger attraction
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for the white oxide than the red oxide has for the oxygen of the oxygenated muriatic acid; (c) that while there is any muriatic acid at liberty to act upon the red oxide of lead, this last will undergo no alteration on the part of the oxygenated muriatic acid, which becomes disengaged and flies off.

59. The gaseous oxygenated muriatic acid when received in water, containing the white, yellow, or red oxide of lead, is absorbed, renders it at first black or rather brown, and then dissolves it. In this manner a super-oxygenated muriate of lead is formed in a yellowish solution. If this solution be precipitated by pot-ash or soda, the oxidized lead is deposited of a brown-red colour. The same superoxygenated muriate of lead is obtained by precipitating it of a brown-red by the alkalis, or by pouring the oxygenated muriatic acid upon the nitrate of lead; in which no precipitate at first appears, but at length it falls down in a brown or red powder. A greater quantity re-dissolves it. We are indebted to Mr. Proust for our knowledge of this salt, which is very different from common muriate of lead.

This super-oxygenated muriate, which is black, will not dissolve in water, and is not very soluble, unless by an excess of the oxygenated muriatic acid. Every white oxide of lead brought into contact with the latter acid, acquires a red colour, and at length a brown or puce colour. The super-oxygenated muriate of lead,

lead, is precipitated of a white colour by ammonia, which being at the same time partly decomposed, immediately decomposes the red oxide of lead in proportion as it falls down. Citizen Vauquelin has re-examined this super-oxygenated oxide of lead and the method of preparing it. It particularly follows from his researches, that out of an hundred parts of red oxide of lead, sixty eight parts of brown oxide are thus obtained, and that a double effect takes place in this mutual action which tends to increase the quantity of brown oxide. In fact, while the oxygenated muriatic acid yields its oxygen to one part of the red oxide, another portion of the oxide is engaged in union with part of the disoxygenated muriatic acid, with which it forms muriate of lead: this second proportion of oxygen separated from one part of the oxide, seizes the other portion of the same oxide, and thus it is that 0,68 of brown oxide is obtained by this process, whereas by the muriatic acid no more than 0,15 are obtained.

60. The brown oxide of lead obtained by either of these processes, has, according to the same chemist, very different properties from those of other oxides of the same metal. It is of a deep shining velvet-brown, similar to the shade which is denominated puce; before the blow-pipe it becomes yellow and melts; upon ignited coals it is reduced with ebullition; when heated in a retort it affords very pure oxygen gas, and becomes re-converted into glass of lead;

lead ; it affords the same gas when it is distilled with the sulphuric acid, and in this respect its habitudes resemble those of the oxide of manganese ; it is insoluble in the nitric acid, but dissolves in the nitrous ; sugar or honey render it soluble in the former. The muriatic acid immediately boils upon it and passes to the state of oxygenated acid. It rapidly decomposes ammonia, and forms nitric acid in one of the products of this decomposition. It inflames sulphur by mere trituration, and causes it to throw out a very strong light, though without detonation ; it does not inflame charcoal. Lastly, the puce-coloured oxide of lead easily unites with olive oil, which it converts into a light brown very solid plaster.

61. The liquid phosphoric acid does not attack lead but very slowly, and gradually converts it into white insoluble phosphate of lead. But the alkaline and soluble phosphates form this salt in an instant, when united with the nitrate of lead, and even by the assistance of heat to the muriate of lead, as I shall soon explain. It is probable that it is by the effect of these double decompositions that the solid phosphate of lead, crystallized, or in deposition, is formed, which at present is met with so frequently in the mines of this metal. This phosphate which appears to become soluble by an excess of phosphoric acid, and even by other acids, is fusible by heat, and takes the form of regular polyhedra by cooling. It is decomposed
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by ignited charcoal, which changes it into phosphorus and lead, while itself passes to the state of carbonic acid. The sulphuric, nitric and muriatic acids, decompose it in the humid way, and afford a method of separating the phosphoric acid. The alkaline carbonates are also decomposed by double attraction.

62. The union of the fluoric and boracic acids with lead is little known. It is only ascertained, that fluuate or borate of lead of sparing solubility, is formed by the effect of the elective attractions, by pouring the soluble fluates and borates into a nitric solution of lead; that these salts are then precipitated into a white insipid powder, and that they may be decomposed by the sulphuric, nitric and muriatic acids, which have a stronger attraction for the oxide of lead than is possessed by the fluoric and boracic acids.

63. Carbonic acid easily unites with the oxide of lead: hence it is that in proportion as this metal is burned by contact of water and of air, the carbonic acid of the atmosphere is gradually absorbed, and causes it to pass to the state of carbonate of lead, which appears even to be soluble in water by means of the carbonic acid. This same solution is effected by charging water with carbonic acid and leaving it afterwards in repose upon the oxide of lead. The water soon becomes turbid, and blackens by the contact of hidro-sulphuret. The soluble or dissolved salts of lead, decomposed by the alkaline carbonates,

carbonates, afford a precipitate of carbonate of lead: this process is the best we know for obtaining this salt. It is by the union of like circumstances that the carbonate of lead is probably formed, which is so abundant in the earth, and is so frequently found among the ores of this metal, as well as among those of copper. Water must have held it in solution, since it is found so frequently under the form of crystals, depositions, stalactites, incrustations, and since when it is analyzed, we find a small quantity of this liquid, as is proved by its decrepitation upon ignited coals, and its distillation in a close apparatus. By fire in closed vessels, it gives out carbonic acid and an oxide of lead. It is easily and speedily reduced by charcoal; the acids dissolve it with effervescence, the product of which is carbonic acid; the ammoniacal sulphuret and its vapour immediately blacken it, and cause its presence to be instantly known.

64. All the metallic acids unite with the oxide of lead, when once formed, and have no action, or at least, a very weak action upon this metal.

a. According to Scheele, lead becomes black when digested in a solution of the arsenic acid, and becomes covered with a white powder, though the supernatant acid does not hold in solution any oxide, of that metal. When treated in filings with twice its weight of solid arsenic acid by distillation, the mixture flows in a transparent mass; a small quantity of arsenious acid rises,

rises, and there remains a milky glass, which when washed affords a plentiful precipitate in white powder, while a portion of arsenic acid is dissolved. We therefore see in this case, that the lead takes from part of the arsenic acid, a portion of its oxygen, and unites in the form of white oxide to another part of this acid. This arseniate of lead is not soluble; it appears to be fusible in white glass: it is formed by precipitating the nitrate and muriate of lead by arsenic acid, which takes from them the oxide of lead.

b. The same chemist has discovered that tungstic acid precipitates and separates oxide of lead from the nitric solution of the metal in a white insoluble tungstate of lead, and that the molybdic acid decomposes the nitrate and muriate of lead, by forming a white abundant deposition with their solutions. He has therefore proved that the tungstic and molybdic acids have a stronger attraction for oxide of lead than nitric acid has; that the molybdic acid has even a stronger attraction than the muriatic, and that the tungstate as well as the molybdate of lead are insoluble in water. We have seen already that this last salt exists native in the form of crystals, or hexahedral plates of a light yellow, in what has been denominated the yellow lead of Bleyberg, and that this native salt was decomposed by the muriatic acid by Klaproth: which seems to contradict the fact announced by Scheele

Scheele of the decomposition of the muriate of lead by the molybdic acid.

c. The chromic acid, as we have seen before, was discovered in combination with the oxide of lead by citizen Vauquelin, in the red lead ore of Siberia. When after having decomposed this salt by the solutions of carbonate of potash, soda or ammonia, (for these three salts have the same property in this respect,) the alkaline solution of the chromate is united with the nitric solution of lead; a new chromate of lead is immediately formed by virtue of double elective attractions, which presents the colour and all the other properties of the native chromate, except the crystallization.

II. Action upon the Bases and the Salts.

§65. THE earths and the alkalis have no action upon lead: these last, nevertheless, favour its oxidation by the air, and particularly by aerated water, on account of the attraction which they tend to exercise upon the oxide of this metal. The earths, particularly flint and alumine, unite very well by the action of fire with the red oxide of lead, and produce a yellow homogeneous vitrification which is ponderous, and is denominated glass of lead, when the proportion of the oxide is very great. It is on account of the strong vitrification which the oxide of lead communicates to earthy substances, that it is used

used as an ingredient in the composition of glass, in the dose of a sixth or even a fifth of the other materials which constitute the vitreous composition. This oxide was formerly used only for the preparation of enamels, and the glass of various kinds of pottery; but the English manufacturers availing themselves of observations upon the accurate fusion of these mixtures, began to increase the dose of this oxide in the composition of their glasses; and in imitation of their work, there have been established in many countries, particularly in France, a number of glass-works, in which the oxide of lead is used in great quantity. By this addition, glasses are obtained speedily and completely fused, homogeneous in their texture, without veins, without bubbles, without blisters, and without defects. These glasses are heavy, icy, of an uniform black appearance in their fracture, of a clear white when viewed by transmitted light, refracting, and strongly dispersing the rays of light, and which produce, when cut into facets, those varied and beautiful colours of the rainbow, which are so much admired in the lustres and chandeliers which are decorated with them. But this glass, so beautiful to the eye, and so useful on account of its cheapness, possesses great inconvenience in the structure of chemical vessels, because it frequently reacts, by the great quantity of lead it contains, upon the matters which are treated in it. It is likewise by means of this combination with the oxide of lead

lead, and the density and homogeneity it communicates to the vitrified mass, that the glass is obtained, so useful in the fabrication of astronomical instruments, and particularly of achromatic telescopes, which is known by the name of flint-glass, and of which the preparation is only difficult with regard to the fabrication of large masses; for nothing is more common than small portions of this composition. This union of lead with vitrified substances is, in many other respects, likewise, a subject for useful and valuable researches on the part of chemistry.

66. The alkaline earths and the alkalis unite very easily with oxide of lead. Citizen Berthollet, in 1788, described the combination of the oxide of lead with lime. Lime-water boiled for a time upon the semi-vitreous oxide of lead, or litharge, dissolves this oxide better than the red. When the solution is evaporated in a retort, it affords very small transparent irised crystals, not more soluble than the lime. The alkaline sulphates decompose this kind of plumbite of lime; for we see here that the oxide of lead performs the action of a weak acid: sulphurated hydrogen gas equally decomposes it; the sulphuric and muriatic acids precipitate lead in the form of sulphate and muriate. This same solution blackens wool, the nails, the hair, the white of an egg, and does not act on the colour of silk, of the skin or of the yolk of egg. Citizen Berthollet observes also, that the simple mixture of the red oxide of lead and

lime, which causes it to pass to a white colour, blackens animal substances; and as this mixture is employed to tinge hair, he announces with reason that it is less noxious than the solutions of silver, which are rashly used for the same purpose. Nevertheless he remarks, that it weakens animal substances, and that this weakening is owing to the lime, because wool does not suffer more from the mixture of the oxide of lead and lime than from the action of lime alone.

Bergman had observed, before Citizen Berthollet, that caustic fixed alkalis dissolve oxide of lead; and this is observed in the precipitate of the solutions of this metal by alkalis, added in excess. Chemists will therefore have to examine the combinations of these bodies, and to determine why the caustic alkalis favour the separation of oxygen from the oxides of lead, as they do with respect to several other metallic oxides, as I have observed in many of the preceding articles.

67. Lead does not act upon the sulphates; it differs much in this respect from tin, which decomposes them, and this difference arises from its less attraction for oxygen. It burns slowly by the assistance of the nitrates; and when upon melted lead slightly ignited, nitre in powder is thrown, very little commotion is excited, and no apparent flame: after the action between these two bodies is terminated, the oxide is found in small yellowish semi-vitrified plates similar to those of litharge.

68. There

68. There is a sensible action between the muriates and lead, and this action has successively given rise to various operations of chemistry and products of the arts. It has long been observed, that a plate of lead steeped in water, charged with the muriate of soda, becomes changed, and soon covered with a white crust of oxide. It is also known that the red oxide of mercury and litharge become white by the contact of muriate of soda, wetted or even dissolved in water: this contact by time and agitation forms one of the processes so much sought after by modern chemists to decompose marine salt, and to separate the soda. It was at first thought that only part was decomposed in this process, and that little muriate was formed; that the decomposition is greater by means of heat, and that it was by this means that the lemon-yellow very bright muriate of lead is prepared in some manufactories, which has lately been much employed in painting under the name of English yellow, particularly for carriages and paper-hangings.

These first notions have been rectified; and the history of the decomposition of marine salt by oxides of lead has been entirely enlightened by the later experiments of Citizen Vauquelin. The following is the result of his works upon this object: Seven parts of litharge well pounded, and one part of muriate of soda, were mixed together or moistened with a quantity of water necessary to give them the consistence of liquid soup, and agitated for many hours to facilitate

their mutual action. The oxide became white with increase of volume, and the mixture, by absorbing the water, acquired a considerable consistence. After having added new quantities of water for four days, the mass was diffused in seven or eight parts of the liquid, and the whole was then filtered; the fluid, which was perceptibly alkaline, contained a small quantity of muriate of lead and muriate of soda: when evaporated to one-tenth of its volume, it afforded crystals of carbonate of soda, rendered opaque by some traces of muriate of lead. The oxide of lead, which is the residue of this lixivium, had gained about one-eighth of increase of weight; it assumed by gentle heat a fine yellow colour, with loss of 0,025: it was insoluble in water. Soda dissolved a portion of oxide, as did also the weak nitric acid. These solvents separate muriate of lead in a pure crystalline form, after having taken up the oxide of lead. Lastly, this mass remaining after the treatment of marine salt by lead appeared to possess all the characters of a muriate of lead, containing an excess of oxide of the same metal.

Citizen Vauquelin concludes from these experiments, (*a*) that the litharge which has served to decompose salt, and, in fact, does decompose it completely when it is sufficient in quantity, becomes a muriate of lead with excess of oxide; (*b*) that the caustic alkalis do not decompose this salt, but only dissolve it;

it; (c) that the attraction of the muriate of lead for an excess of oxide of this metal is the cause of the decomposition of muriate of soda by litharge; (d) that the excess of oxide gives to the muriate of lead the property of assuming a bright yellow colour by heat, which property is not possessed by the simple muriate of lead; (e) that the same excess of lead renders it insoluble in water; (f) that this excess may be taken from the salt by the nitric acid which reduces it to the state of common muriate of lead. He also confirms these useful inductions by proving that caustic soda does not decompose the common muriate of lead, but by converting it to the state of muriate with excess of oxide so well known by its pulverulent form, the yellow colour it acquires by heat, and its decomposition by nitric acid, which changes it into nitrate of lead, and simple muriate of lead. It is therefore proved that the oxide of lead decomposes the muriate of soda by double attraction, namely, that of the oxide for the muriatic acid, and that of muriate of lead for an excess of oxide; that this renders it necessary that a large quantity of oxide should be present for the decomposition; that five-sixth parts at least are employed to form the muriate with excess of oxide: that litharge completely decomposes sea-salt when its quantity is sufficient; whereas soda never completely decomposes muriate of lead, but merely reduces it to the state of muriate with excess of oxide, though
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the carbonate of soda decomposes this salt entirely,

The same chemist, however, has discovered that there is also a sulphate and a nitrate of lead with excess of oxide, and probably that all the salts of lead present the same property or capacity of this double proportion; that when the sulphate and nitrate of lead are decomposed by the alkalis, particularly by ammonia, the substance separated is not an oxide, but a true salt with excess of oxide. He suspects that lime decomposes the muriate of soda by the same mechanism of super-saturation of the muriate of lime in its basis, and the superabundance of lime; a fact which agrees with what I have long ago announced concerning the residue of the decomposition of sal ammoniac by lime, which I showed to be a calcareous muriate with excess of base.

The decomposition of ammoniacal muriate by lead, and particularly by its oxide, has been long known in the laboratories of chemistry. The oxides of this metal triturated with the salt in a mortar, without heat, disengage the ammonia, which is very perceptible by its immediate and powerful odour. By distilling a mixture of one part of the red oxide of lead, and two parts of muriate of ammonia in a retort, very pure and highly caustic ammonia are obtained. If the minium has remained a long time exposed to the air, it affords a small quantity of carbonate of ammonia in this operation

tion : if native or artificial carbonate of lead be used, the ammoniacal carbonate is obtained in crystals by sublimation. The residue of this distillation is muriate of lead, which does not differ from that prepared by the before-mentioned process. This residue of the decomposition of muriate of ammonia by the oxide of lead was formerly much employed, and particular virtues were attributed to it. There is no difference between it and the ordinary muriate of lead, and it is only as the muriate that it is employed in the various operations.

69. The super-oxygenated muriate of pot-ash burns lead with much more activity than nitrate of pot-ash. A mixture of three parts of the salt, and one part of lead, fulminates by a blow of the hammer, and presents a strong flame. When an inflamed body is brought near this mixture it takes fire, though with little energy ; and in this manner a white and very pure oxide of lead may be obtained, from which muriate of pot-ash may be separated by water. The phosphates, the fluates, the borates, and carbonates, undergo no change from lead, nor do they produce any change in that substance ; they are, however, combined with the oxides of this metal by fusion with the blow-pipe, so as to afford yellowish or grey glasses, either opaque or transparent,

K. *Uses.*

K. *Uses.*

70. No metal is more frequently employed than lead, and unfortunately there is no metal more dangerous to the animal economy. Reservoirs, pipes, vessels in which water is preserved or transfused, are enemies which instantly threaten our health. Dreadful examples have shown that the use of this metal in the ordinary purposes of life is frequently productive of colic, jaundice, disorders of the liver, palsy, and other affections, which are the more serious as the cause is frequently concealed or unsuspected. It would therefore be an act of wisdom to proscribe this metal, at least, in economical uses where it is but too frequently applied.

71. The deleterious effects which lead produces in man and animals intitle it to be ranked among narcotic or stupefying bodies: hence the term or conclusion of its poisonous action is palsy, which cannot be cured but by tonic, exciting, or stimulating remedies, more particularly by electricity; and the extreme pains of that particular species of colic characterized by vomiting, and the retraction of the navel which it occasions, give way to powerful evacuations, such as antimonial remedies. We must here remark that lead produces these diseases, whether it exhales during its fusion a vapour in the air, admitted into the system by respiration,

or whether the powder of this metal be diffused in the atmosphere, or its particles be emitted from oil paints in the act of drying; or lastly, whether the water suspends a portion, particularly by means of carbonic acid. The evils to be feared from this source when wine was kept in vessels of lead are truly dreadful, as may be easily deduced from the remark that by its mere passage across the leaden covering of the counters of the sellers of wine were corroded into very perceptible excavations by what was spilled upon them; the same remark is still more cogent against the custom of measuring vinegar in leaden vessels, which produce a constant danger of poison. Tin, which contains much lead, is also noxious, particularly when it is used to retain acid liquors.

72. Hence it becomes difficult to conceive the degree of imprudence which caused, and the evils which might have followed, the advice of certain physicians who have proposed the internal use of lead in several disorders. Enlightened physicians never prescribe it internally, but administer it externally only as a topical, sedative, anti-inflammatory repellent. They are at the same time very circumspect in the external application of this medicine; they are aware that when it is used in disorders of the skin, consisting of swellings or eruptions, it is frequently dangerous to heal them, or repel the humours which contain it. Men without ability or information, who prescribe external applications
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of lead in those disorders, are guilty of the most serious attack upon the public safety, and physicians of skill are frequently called in to heal or mitigate the evils produced by the unskilfulness and audacity of such men. Experience and reason have proved, that sulphureous preparations are the most certain remedy for affections of that description.

73. Lead is much more useful in the arts, where it does not produce the same terrible inconveniences which follow its application in the purposes of life. The covering of buildings, pipes to conduct rain-water, reservoirs, and vessels to contain the different baths for dyeing, are among the principal services it renders to society. Lead is used to line the chambers in which sulphur is burned to fabricate the sulphuric acid. Tea-chests, tobacco-boxes, &c. are lined with this metal, in order to preserve their contents from drying, or from the loss of their odour. It is also used to make balls for artillery.

74. Lead is used as the raw material of several different manufactures. From this metal, as I shall elsewhere observe, are prepared white lead, ceruse, the acetite called salt or sugar of lead, red lead, or minium, together with the yellow semi-vitrified oxide, or litharge, which are useful in glass work, in enamel, in the glazing of pottery and porcelain, the preparation of coloured glasses and false jewellery. The oxides are employed in the extraction of soda,

soda, the fabrication of various colours, and particularly yellow. Lead is mixed with various other oxides, to render them vitrifiable or to modify their colours.

75. Lastly, this metal is a body of the greatest use to chemists in their experiments. It is not only used to form utensils, such as weights, retorts, tubes, capsules for slow evaporation, the furniture of pneumato-chemical vessels, but it is likewise the perpetual subject of experiments and researches; its oxides are the medium of vitrifications, and its solutions are re-agents; its alloys are advantageous instruments; and its attractions also become the means of a variety of decompositions and combinations.

ARTICLE XVIII.

Concerning Iron.

A. History.

1. IRON, formerly considered by chemists as an ignoble and vile metal, is nevertheless the most important and most useful of all metallic substances. Without this metal no art could have arisen: man had remained in the savage state, and disputed for his food by brute strength with the other animals. Without this metal, agriculture could not have existed, nor could the plough

plough have rendered the earth fertile. Without iron, all the other metals would have been of no utility ; for it is by means of this agent that they receive their varied forms and dimensions. Iron alone may be considered as the representative of every other metal ; it may be substituted in the place of any of them, but no metal can afford a substitute for iron. Though the scarcity, the brilliancy, and durability of gold and silver may place them in a higher rank in these respects, yet the service which iron renders to society, entitles it to a higher degree of estimation in the minds of men who are accustomed to think with justice and propriety. It is true that it does not shine with a splendour equally strong ; nature has not decorated it with so beautiful a colour, but its intimate properties are much more precious. All the other metals might in truth be dispensed with ; but iron, on the contrary, is indispensable and necessary. The condition of humanity would be truly miserable without this metal, as is proved by the history of those people with whom the art of working it is still unknown, and who with joy and exultation exchange the gold with which their country is enriched, for morsels of iron which happier and more cultivated nations bring to them in exchange.

2. The philosopher, accordingly, while he studies the progress of the human understanding, and compares the fortune and state of the
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different nations established on various portions of the surface of the globe, will remark, that their iron-works seem, in some measure, to be proportioned to their intelligence, to the advancement of reason among them, and the degree of perfection to which the arts have arrived. When we consider it in this point of view, as the agent by which men in the variety of its uses, and the numerous wants it supplies, acquire enjoyments which would be unknown to them if they did not possess these products of their industry, iron must singularly contribute to extend their ideas, to multiply their knowledge, and to conduct their spirit towards that perfectibility which nature has given no less, as the character of the human species, than as the source of all the advantages it can enjoy. Iron composes the first instrument of machines, and the first mover of mechanics. In the hands of men it governs, and, as it were, subdues all the products of nature. In successive obedience to his power, we behold it change their form, and their properties by the perpetual influence it exercises upon them. In a word, it is the soul of all the arts, and the source of almost every beneficial product; the perfection of works in iron is every where the term or indication of intelligence, the sign of the happiness and prosperity enjoyed by man on the face of the globe. It seems as if nature had connected the lot of humanity in a peculiar manner with the numerous properties of iron, by presenting this
metal

metal in almost every situation, diffused in the greatest abundance, almost constantly upon the surface of the globe, easy to be found, and not concealed in its bowels, as most other metallic substances are, at greater or less depths. Though the poets have characterized the first epocha of the corruption and misery of society, by the name of the iron age, philosophers, on the contrary, have discerned in the epocha at which this metal was wrought, a true renovation of the human species. In their opinion, the numberless advantages which this labour has procured, greatly preponderate over the difficulty, and even the hardship of the labour necessary to procure it.

3. Though a thousand facts in history prove, that the ancients were not acquainted with the art of working iron like the modern nations, the historians of chemistry have nevertheless placed the infancy of their science among the first operators at the forge, whose existence they have admitted almost in the first ages of the world. It is commonly supposed, in the political annals of nations, that the ancients made much more use of copper than of iron, because, the traces of their existence, and the remains of their industry, which have been dug up, as well as the literary monuments of their customs, exhibit most of the instruments and utensils in copper, which are fabricated in iron in modern times. But sufficient attention has not been paid in this estimate of the ancient arts,
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to the easy destructibility of iron, or at least, the much greater durability of copper and its alloys. No doubt the Greeks and Romans made use of iron, much seldomer than copper, in most of the circumstances of life; this is proved by moveables of every description, which researches by digging into the ground of the countries they inhabited, serve every day to discover. But though the action of rust, by destroying their utensils and machines of iron, and leaving those of brass or copper, seems to give the advantage of the latter beyond the former, too many passages in the writings of their historians, their poets, their orators, and their philosophers, which have been transmitted to us, prove, that they knew how to work iron, and to give it the various forms and states, to allow us to doubt the advancement to which they in fact arrived in those works. Their battles, so frequent and so destructive, with iron weapons, alone afford an unanswerable proof, even if a multitude of monuments did not also afford it.

4. Alchemists have qualified iron with the name of Mars, by consecrating it to the God of War, in whose service it has been employed. Its characteristic sign, as well as that of the planet, was a circle surmounted with the prolonged sign of acrid or corrosive, or a kind of barbed point of a dart inclined to the right. The alchemists intended to express by this sign, that with the designation of gold, which they supposed it to contain, though profoundly concealed,

cealed, iron itself possessed an acrid quality, in a certain degree, superabundant, very evident and predominating; and accordingly, this quality presented itself the first in the sign of which it composed the most striking part. From the denomination of Mars given to iron, naturally flowed the appellation martial, which has been successively attributed to numerous preparations made with this metal. There is not in fact, any metal which has been more tormented by chemical agents, or subjected to more experiments and researches; and a list of ferruginous compounds and varied forms, which have been communicated to it, for the purpose of curing disorders, would also be fastidious and of no use in the actual state of the science. The adepts had founded greater hopes, and conceived more elevated projects respecting its medicinal properties, and even concerning the universal medicines extracted from iron, than the alchemists had indulged with respect to their chimerical and absurd hopes, of using it in the discovery of the great work, or philosophers stone. Though the pretensions of each of these have been equally deceitful, it is easy to be presumed, that their laborious researches were not without advantages with regard to chemistry. In this department of inquiry, though they never found what they so assiduously sought after, they often discovered that which they did not seek, and though they were very remote from the expected result of their labours, they nevertheless, gradually

dually advanced to that of true philosophers and men of science.

5. Systematical authors of chemistry have availed themselves of those laborious efforts. They have arranged the discoveries which in a certain respect escaped the possession of alchemists and adepts. They deduced general results respecting the properties of iron; they united them methodically, and composed a regular system by adding the numerous and useful observations of mineralogists, assayers, and metallurgists, who also have singularly multiplied their experiments on the different states of this metal, its natural combinations, the means of separating and obtaining it pure, or of giving it those various properties which render its history so remarkable, and its uses so important. Thus it was that the immense collection of facts which comprehended the study of iron, and which are condensed or collected in many works professedly written on this metal were made. For there is no metal which has been individually treated by a greater number of authors, such as Swedenburg, Bouchu, and Courtivron, Reaumur, Rinman, Bergman, and a multitude of others which it would be useless to mention in this place.

6. In every period of chemical science, and in all the various revolutions to which it has been subjected, iron has been the more particular object of operations more or less complete, and the subject of valuable discoveries. This

metal itself being connected with the principal and most striking events of natural philosophy, has also been of the utmost consequence in the discovery of the mariner's compass, and consequently of navigation. It is the only metal which has been thought to be directly and immediately composed by the union of earth and fire. As it is found in every accurate analysis of all the various classes of bodies, and exhibits every possible colour by the processes of chemical art, it has been considered as one of the primitive and necessary principles of bodies; it has been admitted as the colouring matter of stones, from the most precious to the most common; it is the ingredient which gives all the colours of vegetable structures, however brilliant or dull, and it is the tinging matter to which the blood of animals owes its brilliant purple colour. Philosophers, not content to characterize it by its exclusive property of magnetism, as the reservoir of the fluid to which this force is attributed, a force that in a certain respect constitutes animation in mineral bodies, though it is at present well ascertained that cobalt and nickel partake of this astonishing property, have traced and discovered iron in the tubes of vegetables; they have found it in their ashes; they have pointed it out as the cause of their colour; and by exhibiting it also in the texture of animal matters, they have proceeded to attribute either wholly, or in part, to this metal the existence of the active and most incom-

incomprehensible power which maintains the life of animals ; and if the new and delicate experiments of Scheele had not taught us that manganese which almost always accompanies it, does likewise partake of this property, we might have affirmed, not only as Citizen Haüy observes when speaking of minerals, that when nature takes the pencil, iron is always the colour she uses ; but we might also have ascertained, that when she determines to paint plants, to give them those various tones of colour which fix her attention, and even to heat and to move the organs of animals, iron is always the agent, the instrument, and the moving power which she charges with these important functions.

7. The number of chemists who have made important discoveries on iron, or who have successively examined its properties and combinations, is so considerable that it would be impossible to enumerate them in this place ; and even if we were to attempt this long enumeration, no real advantage would be derived from it. It is much more essential to know in general, that most chemists have added one after the other some facts to its history, and that there is scarcely one who, since the end of the last century, has not had occasion, in the course of his operations, to observe some new object respecting this metal ; that among these laborious men we must particularly distinguish Lemery, Stahl, Geoffroy, Hellot, Macquer, Monnet, Baumé, Bayen, Scheele, Bergman, and Rinman, who

have made the most considerable researches, the most connected inquiries, and the most valuable discoveries respecting iron ; that since the establishment of the pneumatic doctrine, Lavoisier and Citizen Berthollet have, by ingenious arrangements, and by accurate experiments, connected all the facts formerly known to the bases of the modern theory ; that these facts have afforded the French chemists still stronger and more convincing proofs of their doctrine ; that all the discoveries which have since been made, particularly of Citizen Monge, Vandermonde, and Berthollet, on the principal states of iron, and on the substance hitherto named plumbago, as well as those of Ingenhouz, on the combustion of iron in oxygen gas ; of Vanmarum on its inflammation by the electric shock ; of Citizen Delarbre on the iron of Volvic ; of Citizen Vauquelin on that of Elba, &c. have added still more to the evidence and the solidity of the proofs already collected respecting the truth of this doctrine ; and lastly, as we shall see in the whole of this article, the history of iron has gained much in perspicuity, precision, and firmness, by the accurate application which may continually be made to the pneumatic theory respecting it.

8. That which distinguishes iron more especially from every other metallic substance, and renders its literary history more extended and frequently more embarrassed ; that which even appears sometimes to present in the composition of the
facts

facts, contradictions or oppositions, difficult at first to be reconciled, is, that this metal is found and can exist in several states very different from each other; that in each of these states it appears to be very different from itself, to present contradictory properties, and to perform the functions of several different metallic substances. Accordingly Bergman, one of the chemists who has considered the science most philosophically, has doubted, after a profound examination, whether we ought not rather to consider it as constituting several metals more different from each other, than some of those which are distinguished more generally; and whether, in this point of view, cobalt, nickel, and platina, be not even species of iron. All the world knows that marked distinctions exist, as well in their properties as uses between crude, or cast iron, iron properly so called, and forged iron, and lastly steel. In each of these three states the iron presents a great number of varieties, which differ more or less from each other in several of their comparative properties. Hence it is that iron, which in all its several states varies in its colour, its texture, its hardness, its tenacity, its ductility, and its weight, answers so many different purposes in the arts, and is a substitute for many very different metallic substances. But, notwithstanding its numerous varieties, it is well known at present that there is but one species of iron; that when it is very pure it is constantly the same; that in its several states it is

is combined or alloyed with several different substances; that these states or modifications must be regarded as particular compounds, and the rank which they ought to occupy ascertained by the order of their composition. I shall therefore treat of iron properly so called, pure, soft, and ductile iron, in this article; and the varieties of hot and cold short iron, of different cast iron and steels, shall be treated in its history as true combinations, which present themselves to be examined in the methodical series of facts which this history will contain.

B. Physical Properties.

9. IRON possesses a peculiar metallic brilliancy. When we wish to describe its colour, we are obliged to say that it is white, rather livid, inclined to grey and to blue. In its texture it is formed of small fibrous threads, or small grains and small plates very pointed. Tillet affirms, nevertheless, that under the microscope we see a great number of pores or small cavities more perceptible than in copper. It appears that its interior texture, as shown in its fracture, which is more or less fibrous, granulated or lamellated, depends much on the method of its cooling, the pressure it has undergone, the manner of treatment, and the heat under which it has been forged or struck, as we shall elsewhere observe in the examination of all its other physical properties.

10. The

10. The specific gravity of iron of the middle term is in general 7,600, varying in fact between certain limits, as may be seen by consulting the tables of Muschenbroeck, Swedenburg, Brisson, and many other philosophers. In this collection of numerous results we find it marked from 7,600, to 7,895, and even 8,166: it is placed immediately after tin. The hardness of this metal is greater than that of any other substance of this order; and accordingly authors place it in the first rank as to this property. On account of its hardness, it is used to grind, cut, fashion, engrave, and file most natural bodies, stones, wood, and particularly the other metals. It is also the most elastic of metals, and is therefore preferred to all the others for springs of every description.

11. The ductility of iron is also very considerable; but it is in some sort of a particular kind, or rather it is limited by its excessive hardness, or the cohesion of its particles. Though these adhere much more strongly than most of the other metallic substances, it cannot be made into plates as thin as are formed of several other of the latter; the thinnest sheet iron is in fact much thicker than very coarse leaves of lead or tin. For this reason iron is commonly placed in the fourth rank among metals as to its ductility, and this place is given on account of its ductility in the wire-drawers' plates. Its malleability is very limited on account of its firmness, so that its ductility is much more eminent

nent and remarkable. It is known that iron wires, almost as slender as hairs, are drawn, and that perukes are made of them. It is also known that a wire of this metal, of one-tenth of an inch in diameter, supports the weight of four hundred and fifty pounds before it breaks, which cannot be done with any other metal, not even copper and platina, which approach the nearest to it. Muschenbroeck, by examining a parallelipedon of iron, of one-tenth of an inch in diameter, was obliged to use a force of seven hundred and forty pounds to break it; and he remarks on this occasion, that a similar piece of iron forged of horse-shoe nails, which had remained for some time in the hoof of a horse, did not exhibit a greater tenacity. This opinion is therefore a prejudice which arises only from the goodness and purity of the iron made use of for forging those nails.

12. Every one knows the readiness with which iron heats, and the great force of this metal as a conductor of caloric. Though there is not any exact term of comparison of this property of iron with that of other metallic matters, it appears that it is not very strong in iron. In fact, it results from the experiments of Muschenbroeck on the dilatibility of these bodies by heat, that an iron wire, expanded by the heat of boiling water through a space expressed by 73, while that of a similar wire in bulk of lead gives 164; of tin 124; of copper 84. Cassini has estimated the proportion of the dilatibility

tability of iron to that of copper as 10 to 17; or as 27 to 46. G. Juan, by exposing rods or bars of different bodies, three feet in length, to the rays of the sun in Peru, while the mercurial thermometer stood at ten degrees of Reaumur, observed, that iron dilated $0,13\frac{1}{2}$ of a line; steel $0,12\frac{1}{2}$; copper $0,19\frac{1}{2}$; glass $0,03\frac{1}{2}$; and a stone $0,02$. Muschenbroeck has concluded, from these experiments, that among the metals tin dilates the most speedily, after which in succession comes lead, silver, copper, and iron.

13. Iron is one of the most infusible metals. It formerly was considered as the most difficult to fuse; but we at present positively know, that manganese and platina require a more elevated temperature, or a more considerable accumulation of caloric to be fused. Its fusion is estimated at 130 degrees of the thermometer, or pyrometer of alumine of Wedgwood. Mortimer indicates this temperature at 1600 degrees, no doubt, according to the graduation of Fahrenheit. Iron becomes ignited long before it melts; and four degrees, at least, of redness are distinguished in the arts: the first is, the low red heat; the second cherry red; the third bright red; and the fourth a white heat, which is distinguished by the word incandescence. Philosophers have long since observed, that strong percussion ignites it. After Boyle, who first insisted on this phenomenon, the journal of Bressaw mentions a workman, who, by five or six strokes of the hammer, rendered iron red-hot;

hot; and Swedenburg remarked, that a square flat piece of iron becomes easily red-hot, if struck upon the anvil by its flat faces, and not its edges or angles. It is almost superfluous to observe in this place, that the heat produced by the percussion of iron, is the effect of compressed caloric, which exfudes on all sides from the condensed particles of the iron, and that the red heat it assumes in consequence of those percussions, is only the same substance much more condensed, and possessing a much more rapid motion, which darts through the pores of the iron, and produces the sensation of light in our eyes.

14. Cast iron flows with various degrees of liquidity, pasty or soft, and moveable in the extreme like water itself. We must observe, that all workmen who work in iron, do not suppose the pure metal capable of fusion, and seem in this respect to contradict philosophical men. This arises from the circumstance that, in the arts, iron is never fused without causing it to undergo a combustion more or less advanced, and consequently an alteration, more or less considerable, so that after its fusion it is no longer iron properly so called, for workmen distinguish with great precision and delicacy, the several states of iron, because it is owing to these different states that the particular properties discernible in their operations are produced. In the operations of chemistry, on the contrary, small portions of iron are fused in vessels exactly closed in such a manner that they undergo

undergo no change; and it is of this fusion in the small way, though impracticable on a large scale, that chemists speak. When iron is brought to a state of fusion, it does not appear to be perceptibly volatile, or, at least, the fire required to sublime it must be enormous; if it be cooled slowly it crystallizes in regular octahedrons, inserted in each other so as to form a very agreeable kind of vegetation or dendrites. Nature sometimes presents it in this form, but in a state of combination.

15. Iron is rapidly penetrated by the electric fluid; it is one of the best conductors of electricity; and accordingly, since the discoveries of Franklin on the identity of atmospheric thunder and the electric spark, it is employed with great success to fabricate those elevated conductors, which are appropriated, by their gilded and unalterable terminations in a point, to attract without noise, and rapidly to transport the electric matter into the earth or into water, where their inferior extremity terminates. It has been long observed, that iron thus vertically placed in an elevated situation of the atmosphere, if it remains a long time, or be struck with the electric fluid of lightning, assumes the properties of a magnet. If iron be struck in the air by the electric shock it takes fire; but as this phenomenon belongs to the history of its combustion I shall speak of it in another place.

16. Magnetism is one of the most characteristic, and at the same time, most singular of the

properties of iron. It was long supposed to be particular and individual in this metal; but it is at present well proved, that cobalt and nickel also possess it. Nevertheless all the experiments relative to the magnetism of these two last metals not having been made either with the same accuracy, or to the same extent, as upon iron, the principal phenomena of this force have been well observed only in the latter metal. The following are the principal facts, which in the study of the magnetism of iron, are interesting to the naturalist and the chemist, and of which Citizen Haüy has consequently given an explanation in the article of the ores of iron, extracted from his great work of mineralogy.

A. The forces which give a particular direction to iron suspended at liberty, emanate from the terrestrial globe: and many philosophers think that these forces have their origin in a peculiar body, placed in the centre of the globe, which acts like a very powerful magnet.

B. The forces which draw a magnetic needle in opposite directions, towards the north and towards the south, are equal, as Citizen Coulomb proved, by finding exactly the same weight in a magnetized needle, as it possessed before it was rendered magnetic.

C. It has sometimes been observed, that small pieces of load-stone recently extracted from the earth and laid in the same position which they had before their extraction, have their poles situated in an opposite direction from that which
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ought to have taken place on the hypothesis of their having acquired their magnetism by the action of a magnet placed in the centre of the globe. Æpinus has removed this difficulty by supposing in the mines of load-stone, as is observed in artificial magnetic bars of iron, that which he calls *consequent points*, that is to say, a series of contrary poles are formed in a short space by the absorption and accumulation of the magnetic fluid; a series which can exist in a detached fragment of ore; so that the two poles which terminate it may be otherwise turned than in pieces charged or armed with the ordinary magnetism.

D. Magnetism exists only in metallic iron, or in iron very little oxidized; but we must not judge of its absence, or its modification in small pieces by very strong bars, because the force of these must destroy the magnetism of the pieces; for by taking very weak suspended needles to try those pieces as Citizen Haüy did, they all exhibited this magnetism.

E. It is possible that iron ores may have escaped the magnetic action of the globe, if they were situated so that their axis should be perpendicular to the direction of the magnetic meridian of their native place.

F. There are many varieties in the energy of the magnetic force of iron ores; and in order to avoid a conclusion opposite to the truth, we must not confine ourselves to a single observation: they must be sufficiently multiplied, as
well

well with regard to the magnetic bar or needle made use of as the relative position of the particle examined, and the bar itself or the needle, which seems to determine its state.

G. All the portions of iron buried in the earth, and not overcharged with oxygen, are natural magnets, of which the degrees of force vary through their extended limits: so that we ought not to consider the loadstone as a separate species in mineralogy. This new truth is very different from the former opinions of mineralogists.

Iron is a very good conductor of animal electricity, at present known by the name of Galvanism, and it must, by this remarkable property, have influence on the life and motions of living animals: accordingly, notwithstanding the little confidence which is due from enlightened men to the blind, enthusiastical, and audacious empyricism which has announced such wonderful virtues in the external application of points of iron suspended or drawn along the surface of bodies at certain distances, or placed very near some of its regions, it must not however be denied, that we have not yet properly estimated the effects which these applications, well directed and united with those of other metallic plates communicating with the former, may produce upon animals, when we shall be more enlightened than at present, respecting the order and the phenomena of the new modification of the irritability of the living subject which has
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been discovered some years ago in Italy. We must still multiply and greatly vary our experiments and inquiries respecting this force so remarkable in the energies of life, before we can pretend to decide in any respect

18. The taste and smell are also two very distinct and very evident properties in iron. If we hold a piece of iron for some time in hand, and afterwards hold it at a little distance from the nose, we may discern its odour and quality. However slightly iron be touched, this metal always leaves upon the skin a slight covering sufficient to show its presence by its impression on the olfactory nerves; and as in this case there is no immediate application of iron upon the nerves, it follows necessarily that the particles of iron must be transported by a current of air upon the olfactory nervous membrane: we must therefore conclude that this metal is surrounded by an atmosphere which holds it in solution, and is saturated with it. Its taste is sufficiently strong to excite the impression of an acrid or astringent quality in the mouth, when it is kept there for some time. Physicians with reason attribute the medicinal properties of iron to the action which this taste exercises upon the irritable membranes, and the nerves of the stomach and intestines. We must not confound this effect of the metallic state with that which the oxides of iron produce, by carrying, like many other metallic oxides, the enlivening and bracing property of oxygen to all the excitable

excitable organs of the living animal economy; but we must advert to the fact that these two forces act together in the viscera when most medical preparations are administered.

19. Iron not only stands alone in the property of becoming ignited by pressure and violent friction which on account of its property, becomes red-hot, and takes fire in the air when strongly struck by a hard stone, but it also enjoys almost exclusively the property of passing speedily into the last vascular ramifications of living animals, of becoming filtrated through the pores of the roots of plants, and by the chyliferous vessels into the sanguine vessels of animals; of contributing to colour their fluids; of becoming fixed in their solids; of entering as a constituent part into their nutrition, and performing a function in the very composition of their organs. Among all metallic substances, it is the least inimical to the vital faculty, and carries its stimulating energy to the extreme of the sensible and irritable fibres. It is in no respect poisonous, but merely augments the activity and force of the vital principle. It requires to be carried as a constituent principle to a determinate proportion in the composition of organic substances. Some physiologists have thought that it is formed in the organs of animals, and as a proof, they have urged the composition of the blood in the eggs of birds during incubation, a composition accompanied with iron from the first instant that the blood appears with
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its red colour; whereas, according to them, there is not found the smallest trace of this metal in the egg before the appearance of the ruddy sanguine fluid; but it is not yet strictly proved that the unhatched egg does not contain iron; nor that the blood of the chicken, at the moment of its first composition, does in fact contain it.

C. *Natural History.*

20. Nature, as I have already observed, has diffused iron with liberal abundance over almost every point of the globe, and nothing is in fact more frequently met with among fossil productions than the ores of this metal. We might in contemplating this liberality be disposed to affirm, that this circumstance was intended to advise man of the great advantages he might obtain from these ores, and that they are presented at the surface of the earth, in order to fix his attention with greater speed and certainty, and to engage him to collect and treat them in such a manner as to obtain the metal they contain. The forms of these ores, their colour, their texture, and their composition, are very singularly varied; and accordingly the mineralogical collections of this genus are multiplied, and present to the eye a very numerous and rich variety of specimens. Hence we may easily conceive that mineralogists, in their me-

thodical classifications founded upon the forms, the colour, and the texture of bodies rather than upon their intimate nature, must have admitted a great number of species in the ores of iron. There are in fact still existing several modern works in which more than thirty different species are reckoned. But the chemical examination which has within a few years been made, enables us to place certain limits to this irregular determination of the species, to include their number in narrower bounds, to dispose the same species in a more precise and natural order, and to place in the almost indeterminate series of varieties those differences between them, which, for the most part, consist in very slight changes in their properties.

21. After having shown that iron is perhaps of all the metals, that of which the ores present the greatest number of differences or variations in their nature, of which the natural compositions are the most discordant and diversified; after having in this place repeated more especially that we ought not to reckon among the true ores of this metal, any but those in which its quantity is so abundant, that they can be explored with profit, or at least so as to constitute the basis of their composition; a condition, without which, we should be soon under the necessity of multiplying these ores to infinity, and of considering almost every fossil as belonging to this class; I shall observe, that it is more particularly in the distinction of these
numerous

numerous minerals, that the method established in the general article of the history of metals presents the greatest number of advantages, and promises the most perspicuity. The five principal states which have been established for the generality of metallic ores, may be admitted in the distinction of the ores of iron, 1. That of native metal; 2. Of its alloys; 3. Its combinations with combustible bodies; 4. Its state of oxide; 5. Its salts. In each of these states, as it were under so many genera, the species and varieties of ores which naturalists have discovered, arrange themselves, however numerous or diversified they may be.

22. Though the existence of native iron is still a kind of unrefolved problem among mineralogists, and though it is very natural to suppose, with the most celebrated among them, that the insulated pieces which have been designated under this name, are only the accidental products of ancient fusions or subterraneous fires, it is, nevertheless, proper to be observed, that Margraff affirms, that it is found in veins at Libenstock in Saxony, and Adamson affirms, that it is common in Senegal, and that Pallas discovered in Siberia a mass of the weight of 1600 pounds. In this block, in fact, there are cavities which denotes fusion and swelling up; nevertheless, from the just observations of Bergman, it exhibits various proofs that it was not fused by art. Besides, its situation which announces this truth, the stone which fill its

cavities is very different from the scum or scoria of the furnaces; the iron is very malleable in the cold, and at a moderate temperature; but it is brittle at the red heat; in all trials, its habitudes are the same as those of forged iron: it affords sulphurated hydrogen gas by muriatic acid.

23. It very seldom happens, that iron is found alloyed with other metallic matters in proportions sufficiently large, that this kind of alloy should be considered as belonging to the ores of this metal. I am not yet acquainted with any in this genus, excepting that which Citizen Haüy comprehends in his fourth species under the denomination of arseniated iron. It is also the species of pretended mis-pickel or arsenical iron ore, which Romé de Lisle improperly denominated white ore of arsenic, and other mineralogists have designated by the phrase of native iron mixed with arsenic. Though some of these, more particularly De Born, have supposed that this ore is a triple combination of arsenic iron and sulphur, the latter, hath himself mentioned in his description, a case in which the quantity of sulphur is, as he affirms, very small. This natural alloy is sometimes argentiferous, and is then called the white silver ore: it is the *weisserz* of the Saxons. The most evident character of this alloyed metal, which is of a brilliant white grey, and of a lamellated brittle texture, is to present crystals in right prisms with rhombic bases, of which the angles are between

between 103 and 77 degrees ; which is also the form of its integrant particles or nucleus. It is sometimes modified by a dihedral summit, with triangular faces united upon an edge parallel to a short diagonal of the rhomb. The surface of these triangles being inclined to each other in about 150 degrees, is striated in a direction parallel to the border upon which they rest. We must not confound this ore with the true arsenical pyrites hereafter to be described, which differs from it in several essential particulars as well as in its composition.

24. In the order of natural combinations of iron with combustible bodies not metallic, none have yet been discovered and well analyzed, except those it presents with carbon and with sulphur. Besides these two compounds, we may expect that chemistry will hereafter discover that of iron with phosphorus, which may be suspected to exist in nature, though it has not yet been discovered. The carburet and sulphuret of iron are entitled to the qualification of true species of iron ore or mineralized iron, though the latter has been seldom treated, and the former never in order to obtain the metal, notwithstanding which, in a systematical order, we cannot refer these metalliferous compounds to any other place.

The carburet of iron formerly known by the name of lead ore, black chalk, false galena, mica of the painters, and confounded with the sulphuret of molybdena on account of some
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analogies in its form, colour, texture, and even its uses, was first analyzed by Scheele, who discovered its resemblance to charcoal, and its ferruginous nature, after which its qualities were well determined, by Citizen Vauquelin, Berthollet, and Monge, who ascertained that it is a combination of 0,90 of carbon, and 0,10 of iron. It is found in masses, in small layers, and even in veins more or less considerable in the primitive mountains between beds of quartz, feldspar, clay, and chalk; in the Pyrennees, in Spain, and in Germany. It is dug out of the earth in a very pure and soft state in Cumberland. It is also found in America and Africa. This substance is capable of crystallizing in octahedrons; its colour is a deep grey or blackish blue, metallic, shining, greasy to the touch, and of tuberculated fracture; it very easily blackens the hands, may be crushed into a fine soft powder adhering to the bodies by mere friction, and leaving upon paper and white bodies in general a black trace, which all the world is acquainted with in the black-lead pencil. When kept for a long time in a red heat it burns, emitting much carbonic acid, and leaves after its combustion a reddish oxide of iron. Water passing through this ignited carburet also burns it by decomposing it, and affording carbonic acid gas; the acids produce no other effect than to purify it by dissolving the alumine and iron with which it is often mixed. It decomposes the sulphates, and
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changes them into sulphurets; it burns by means of nitrate of pot-ash, which causes it to detonate or much more effectually with the super-oxygenated muriate of pot-ash, which serves to ascertain its nature very accurately. It is useful in making pencils, in diminishing the friction of metallic or wooden wheels, in covering and defending from rust the surfaces of iron instruments, in communicating a leaden metallic colour to many bodies, in lining, or even entirely fabricating crucibles, and in forming lutes upon earthen or glass retorts, &c.

25. The sulphuret of iron, or natural combination of sulphur and iron, has been named pyrites in mineralogy, because it is very proper to maintain combustion, or to become ignited by the stroke of the steel, or to give rise to subterraneous fires. It was formerly called marcasite. This is one of the ores with which naturalists have been most busily occupied. Henckel studied and described it to a great extent in his *Pyritologia*, in which he has in fact comprehended the history of all the ores, particularly the sulphureous, which he has compared and considered very amply. This compound has also exercised the genius of the moderns on account of the diversity and singularity of its forms. It is an interesting object to the arts in which it is frequently and abundantly employed, particularly to extract the sulphur, and to treat various metals.

After the carbonate of lime, which Citizen Haüy

Haüy with truth presents as the mineral Proteus, the sulphuret of iron is a substance which presents the greatest number of different forms. He has already observed thirteen regular distinct varieties. Many of them have the cube for their primitive form, and others appear to be derived from the octahedron: such is the variety which crystallizes like the trapezoidal granite. He observes that the cube cannot be considered as the primitive form in the sulphuret of iron, except when it is smooth; that that which has its face striated, and in three directions perpendicular to each other, is only the commencement of a dodecahedron. Among the principal varieties of the form which this skilful mineralogist distinguishes, I shall point out:

- A.* The smooth cube, or primitive form.
- B.* The regular octahedron.
- C.* The cubo octahedron.
- D.* The dodecahedron, with pentagonal planes.
- E.* The cube striated in three directions.
- F.* The icosaedron or figure, with twenty triangular faces, eight equilateral, and twelve isosceles.
- G.* The polytrigon of thirty-six triangles, twelve isosceles acute angled, and twenty-four obtuse angled.
- H.* The plagihedron, in which each angle of the cube is intercepted by three faces situated slope-wise.

Besides these forms, determined and ingeniously designated by Citizen Haüy, we find the
sulphuret

fulphuret of iron in various grouped crystals, in globes, studded with points of octahedrons, in polished worn spheres, in striated and radiated crystals, in cylinders, in dendrites, in stalactites, in incrustations, in irregular figures which have been compared to all kinds of bodies ; it is frequently deposited in organic matters, which serve as a mould. Hence we have pyrites in the forms of shells and fish.

The fulphuret of iron is almost always of a golden yellow colour, more or less brilliant. In this respect there are two very evident varieties, the brilliant gold, and the tarnished or pale golden colour. We must not consider as a simple variety of colour the brown fulphuret of iron which some mineralogists have denoted by the name of hepatic iron. This is a fulphuret in the state of decomposition, of which the state has not yet been well appreciated, but which has manifestly passed from the brilliant state to the brown colour, more or less dull, since we find some which are brown without, and still beautiful within, whereas others have become brown to their very centre. They are usually more friable in this state than when their tinge is brilliant and metallic. There are certainly in these three distinct colours, as well as in the two kinds of primitive form of fulphuret of iron, differences not yet determined, which depend on their intimate nature, and would require new researches to determine their composition.

The

The sulphuret of iron is fusible and inflammable, it suffers its sulphur to escape by heat; it is very brittle; its sulphur may be obtained almost by fusion, and very little by sublimation. When exposed to the air more especially, after having been moistened, it cracks, softens, becomes hot and covered with saline crystals of sulphate of iron, and totally changes into this species of salt, which shows that the sulphur has burned, become acidified, and the iron oxidized. This phenomenon which is usually applied in the large way for extracting the sulphate of iron was formerly called the vitrification of pyrites; it must be considered as a slow combustion or natural sulphatization. The water is decomposed by this operation; and in that case sulphurated hydrogen gas is disengaged which often takes fire spontaneously and to which the formation of volcanos has been attributed. The acids by attacking the native sulphuret of iron, more particularly the muriatic, develop sulphurated hydrogen gas. The nitrates burn them with detonation at an elevated temperature, and the super-oxygenated muriate of pot-ash excludes it with flame by mere percussion. The chemical analysis of native sulphuret of iron has shown not only the iron and sulphur of which the proportions vary, and which are the most abundant principles, but also flex and alumine. Sometimes gold is disseminated in this mineral which is then called *auriferous pyrites*, and we have likewise
heard

heard of argentiferous pyrites. The examination which has been made of many of these compounds has proved that they vary much in the nature and proportion of their component parts.

26. After the sulphuret of iron we may attend to that species of ore which Citizen Haüy has denominated *arseniated iron*, which is the grey ore of arsenic, or orpiment of Romé. The quantity more or less considerable, and always very perceptible, of sulphur which is contained in this ore, distinguishes it sufficiently from arseniated iron and true mispickel. It never possesses the regular crystalline form of the latter, for it has yet been found only in irregular masses. Citizen Vauquelin has analyzed pieces from two different places, and found the proportion of sulphur to the iron nearly as four to five; that of the arsenic was very variable, for in one specimen it was twice the quantity of iron, and in another six or seven times that quantity. We may call this species arseniated sulphuret of iron: it is not a simple variety of the preceding ore, because its properties are essentially different.

27. The fourth order to which iron ores are referrible, includes the various degrees of oxidation of this metal. Among them we must comprehend, as truly distinct ores in their nature and proportions, the four species named by Citizen Haüy *oxidulated iron*, *pyroctous iron*, *oligist iron*, and *oxidized iron*. Each of these

these denominations applied either to the state of the combustion, or to some of the properties of the species will, with regard to the method I have adopted, present only the several degrees of oxidation. This mineralogist by analogy with the denomination acidule, in the nomenclature, gives the name of oxidulated iron to that species of ore which is formed by iron united to so small a quantity of oxygen as to permit it to act strongly upon the magnet. It is the blackish octahedral iron and obedient to the magnet of Romé de Lisle. This species most commonly crystallizes in octahedrons, as the samples from Sweden, Dalecarlia, and Corfica, which are from a few millemetres to two or three centimetres in diameter. These crystals are usually engaged or enveloped in blackish or greenish foliated steatites; they are often of a brilliant and specular black colour; sometimes their surface is dull, and covered with a small envelope of the steatites in which they are plunged. They are very brittle and lamellated in their texture; their powder is blackish, and strongly attracted by the magnet; in their entire state they possess all the properties of a magnet, more particularly that of polarity. To this species of iron ore more particularly appertains those pieces which are naturally and strongly enough magnetized to admit of their being sawed out and armed under the denomination of magnets. I call this species of ore, the oxidule of iron. It appears to be
indebted

indebted to water for its formation and crystallization. Under this point of view it may be contrasted with the following species.

28. The second species of the same order is denominated by Citizen Haüy *pyrocete iron*, that is to say, *having the region of fire for its country*, because it has been proved by Citizen Delarbre, that the varieties of this species so abundant at Volvic, Puy-de-Dome, and Mount-d'-Or, are a product of volatilization operated by the fire of volcanos. It has often been denominated specular iron ore on account of its brilliant surface. This ore is always in the form of thin plates, of a beautiful polish, brittle like glass, and having the same fracture. Romé de Lisle considered its crystals as a modification of the aluminiform octahedron. If we suppose that two sections be made in a regular octahedron at little distances from the two opposite faces parallel to the sections, there would result from these two sections three segments, of which the middle would have for its basis two regular hexagons, and for its lateral faces six trapeziums, alternately inclined in opposite directions. To this middle segment it was that Romé de Lisle referred the crystals of specular iron ore here mentioned. But Citizen Haüy perceiving that the lateral faces of pyrocete iron were more sensibly inclined to the bases than they would have been in the hypotheses of the segment before mentioned, and the goniometre having given him

an angle of one hundred and twenty-one degrees and a half, instead of one hundred and nine and a half, which they would in that case have had; he concluded that the resemblance from the assortment of the planes had deceived the celebrated Romé de Lisle, and that this is not the source of their singular form. He adds that this form is subject to different modifications. This oxide of iron when broken affords a blackish powder less deep than that of the preceding ore, having a reddish tinge which denotes an oxidation somewhat stronger than in the oxidule before described. Accordingly it is less sensible to the magnetic bar, and is itself a much weaker magnet than the preceding. I denominate it pyroctous oxidule of iron.

29. The third species of native oxide of iron was designated by Citizen Haüy by the name of oligist-iron, that is to say, which is very slightly in the metallic state. This species, as he observed, affords by trituration or by the file a red powder, which denotes an oxidation much more advanced than the two preceding, particularly the first. The black iron ores or specular ores of the Isle of Elba, and of Framont are the most remarkable varieties of this species. Perhaps the expression of oxide of iron might have been sufficient to denote this species, with the addition of an epithet to distinguish it from the following, which contains more oxygen. This oligist oxide is in

brilliant shaded plates with crystals which appear to depend on the cube: The varieties of forms which this produces according to the law of diminution, is particularly remarkable in those fine brilliant specimens, tinged with various shades of colour, which are abundantly obtained from the Isle of Elba, and constitute the ornaments of cabinets. We may particularly distinguish among the varieties, and form of this black oxide of iron, formerly called the specular oxide, and confounded with several very different species: *a.* That in very obtuse rhomboids; *b.* that in six pentagons, and eighteen triangles: these are commonly called specular iron in large nodules, in small nodules, in scales, lenticular, micaceous, and they often present at their surface the bright reflections of prismatic colours. This species is much less attracted by the loadstone, and is much less magnetical itself than the two preceding ores; which evidently arises from the greater quantity of oxygen it contains. The reddish powder which is obtained by trituration or the action of the file is unctuous, and easily forms a paste with water. In this species as well as in the two preceding, the number of varieties may be multiplied. But I must here observe, that these ores which are very different from the foregoing, though they appear to be distinguished only by a somewhat larger dose of oxygen, afford very excellent iron, very easy to be obtained in working them. The varieties

varieties they afford are the most beautiful and most ornamental for collections of all the iron ores.

30. Lastly, in the fourth and last rank of the oxides of iron which nature presents among the ores of this metal, comes the species which Citizen Haüy denominates oxidized iron, to denote, by opposing this denomination to those of the three former, that the present is much more strongly charged, and even saturated with oxygen, being, in fact, at the complete state of oxidation. This true oxide of iron has not the black colour of the three foregoing; it is more or less red, brown, or yellow; its powder, for it is very friable, has a lighter shade than even that of the oligist oxide. It does not assume any determinate crystalline form, except that its particles, which are most commonly condensed in the hard concretions it forms, are arranged in small radiations from the common centre, and diverge in rays outside of the piece it forms. In this last case, and when it has at the same time a more or less deep red or brown colour, it is called hematite, on account of this tinge, which resembles blood. The simple aspect of hematite proves, that it is a true stalactite; it is often found tuberculated, and deposited in strata, each formed of fibres connected together. It has received various different denominations according to the diversity of figures which it affects; it has been denominated *intestinal*, or tuberculated, when it resembles

resembles the exterior tubercles of the intestines; *botrytes*, when it resembles a bunch of grapes; and *needled*, when it exhibits slender prisms resembling that instrument. It has also been distinguished by its colours, and its texture, into red, brown, black, compact, brittle, soft hematites, and to this denomination the sanguine and burnishing stone must be referred. These last varieties exhibit a metallic appearance by polishing; they are the least oxidized, and approach to the oligist iron: they sometimes contain particles almost metallic: they pass easily to the state of black oxide attracted by the magnet, and even become magnets themselves when heated. The eisenram of the Germans, or red micaceous iron, must also be considered as an inferior variety to the hematitical oxides of iron.

Citizen Haüy reckons, as a second variety of the species of oxidized iron, that which mineralogists have denominated the bog-iron. Under this variety he unites the *ætites*, iron ores in grains, or in compact masses, more or less yellow, in powder, or in soft earth, which hardens in the air, and has been denominated *martial ochre*, of a soft texture, leaving traces upon paper, and also called red chalk. The name of *Ætites*, or *eagle-stone*, has been given to a kind of hollow geodes of oxide of iron, often mixed with a greater or less quantity of silice and alumine, containing some concretions in their cavity, and affording a slight noise

by agitation, in consequence of the stroke of those small bodies; they are of a dull pale colour; composed of concentric layers of different magnitudes, of an oval or polygonal form, often polished without. The name of eagle-stone has been applied to them, because it has been pretended that those birds convey them to their nests.

Iron ore, in grains, is a deep brown or pale oxide, formed like the *Ætites*, of concentric strata, but without any interior cavity, more or less rounded, usually of little bulk, but variable from the size of a pin's head to that of a small pistol ball. The small grains are much more common than those which are larger; they are often agglutinated in considerable masses, forming immense aggregates of several yards in depth in the earth, and sometimes of several hundred yards in extent. The soil of several districts appears to be entirely composed of this substance; several Departments of France abound with them, and they constitute the greatest part of the ores which are explored in France. When we observe this astonishing concretion of the grains of the oxide of iron, resembling in magnitude the eggs of fish or insects, and, by analogy, called oolites, each of which is formed of several concentric layers evidently applied by water agitated round a central particle, the imagination can scarcely grasp the immensity of labour which Nature must have performed to fabricate each of those grains, and to accumulate

late the numberless millions deposited on extensive grounds, and of which the quantity is inexhaustible.

The brown oxide of iron, in a compact mass, belongs, properly speaking, to the bog-ores of the mineralogists. This subordinate variety has neither the appearance of hematite, nor the form of geodes, nor that of grains. It is found in regular blocks, more or less dense, or friable, solid or cracked, reddish, or yellowish-brown, shining, or dull, smooth, or granulated in their fracture, frequently in parallelopipedons or irregular and basaltiform masses, connected together or deposited in continued beds or veins within the earth, which is found in the bottom of vallies, frequently below marshy grounds, and are worked in many countries, though, in general, they afford the worst iron, namely, the cold short iron. We shall soon explain the cause of this last phenomenon. This bog-ore does not become black as readily as hematites by fire; it often contains much flint and alumine, and seldom lime.

The earths, which have been denominated *martial ochres*, are merely pulverized, or agglutinated fragments of the preceding ores, or the remains of the slow decomposition of the sulphurets of iron, exposed to the action of air and water. These oxides can seldom be worked like iron ores, they must rather be considered as earthy, siliceous, or argillaceous mixtures, of which the iron, at different states of oxidation,

yellow, straw, red, brown, or dull, constitute only a small portion.

With regard to the red chalk, properly so called, which Citizen Haüy denominates *graphic oxidized iron*, it is another particular mixture, of very fine red oxide of iron with clay, which nature appears to have kneaded together in water, and deposited at the bottom of the fluid in strata, more or less fixed or dense; of a soft, fat, unctuous texture, easy to cut, and wearing, and becoming polished by friction. It has different shades, density, and grain. Citizen Haüy affirms, that he has seen pencils of red chalk converted into magnets by the action of fire; and, on this occasion, he repeats the observation of Lelievre, that nothing more is necessary than to heat a fragment of oxide of iron with the blow-pipe, in order to give it magnetic poles.

The native ferruginous salts comprised in the fifth and last order of the ores of this metal, are still more numerous than those which were pointed out in the natural history of lead. It is easy to explain this multiplicity, when we consider how abundantly this metal is diffused within, and at the surface of the earth, and in how many places it is found, to what numberless circumstances and re-actions it is exposed, and with what facility it obeys the chemical attractions in its state of oxide: it has been found combined with the sulphuric, phosphoric, carbonic, tungstic, and prussic acids, and

we

we may suspect that it exists also united with the muriatic, fluoric, arsenic, molybdic, and chromic acids, though it has not been yet found in these last five states. We must not forget that mineralogy, though very much advanced by modern chemists, from the time of Bayen, Bergman, and Scheele, to that of Klaproth, and Citizen Vauquelin, is still in its infancy, and that, notwithstanding the labours and multiplied discoveries, for which it is indebted to chemistry, during the last thirty years, we find that those valuable researches are but a small part of the whole which remains to be done.

32. The sulphate of iron exists very frequently in nature. It manifestly arises from the slow combustion of the native sulphuret of this metal: it is often dissolved in waters; sometimes it is found solid in stalactites, in depositions, seldom in greenish rhomboidal crystals, which were formerly called green copperas. It is known by its colour, its acrid and styptic taste, and its form. Most commonly it is efflorescent, half-dried, deprived of its water of crystallization, and white: in this state it was formerly denominated *sory*. When more decomposed it assumes a yellow colour, having lost more water, and absorbed more oxygen from the atmosphere, it was denoted in the ancient mineralogy by the name of *misy* or *missy*. Lastly, when it had lost a portion of its acid, when its oxide was disengaged, and still more oxygenated

ted than in the preceding case, so as to have acquired a red colour, it then constituted *colcothar*, or chalcitis of the ancient mineralogists. All the modifications of native sulphuret of iron, more or less decomposed and altered, were in general called *atramentary stones*; and as by mixture with some inflammable substances it frequently affected the black colour, the name *melantery* was particularly applied to it in this last very frequent circumstance. To these notions we must add, that in those places where nature presents this combination in sufficient abundance, particularly when dissolved in water, the arts ought to derive an advantage from the same, either by evaporating, to obtain the sulphate of iron, a very useful salt in many manufactures, as I shall hereafter show, or to prepare on the spot various compounds which are constantly of use for the purposes of human life. Nevertheless, this natural treasure is too often neglected.

33. The phosphate of iron has not yet been comprehended by mineralogists in the enumeration of the many species of iron ores which have been distinguished and frequently described with great minuteness. The exact and skilful Haüy is contented to announce at the end of the history of oxidized iron, of the variety which he calls bog-ore, the possibility of a direct combination of iron and phosphoric acid in nature. That which he announces as possible, is, nevertheless, admitted as real by modern chemists,

chemists. The pretended particular kind of iron, which Bergman distinguished from iron by the name of *syderite*, or *water-iron*, is this native phosphate. It is true, that it has not, perhaps, been met with very pure and well separated from the other species, particularly from the yellow oxides of iron in the masses wherein it is most commonly found annexed; but we may presume that it exists alone and independent of any other ores of this metal, and that mineralogists will soon learn to distinguish it, and perhaps to discover it pure, and in the crystalline form, in those places where the bog-ore is met with. Hitherto it has only been admitted in this species of ore. It has been ascertained that there is scarcely any oxide of native iron, particularly in marshy places, in hollow grounds covered with vegetables, which does not contain more or less of phosphate of iron, and that the bad quality of cold short iron, particularly obtained from these ores, is to be attributed to this substance. It is very common to find in the bog-ores, portions which are more coloured, more dense, more saline, and distinguished from the rest of the mass of simple oxides, as grains are disseminated in paste. These particles have appeared to me to be pure phosphate of iron, and I have no doubt but that it will hereafter not only be extracted from these ores, but found separately in nature. The phosphate of iron is strongly characterized by its property of forming a phosphuret when
heated

heated with charcoal. It precipitates from its sulphuric solution in a very heavy white powder, though it long remains in a state of division; we shall see that by this phenomenon the cold short iron arising from many bog-ores has been discovered and analyzed, and that it contains phosphorus, and not the phosphate of iron, as has been ascertained and repeated in a great number of chemical writings. It is by the very effect of the action of the sulphuric acid on this phosphuret of iron, and by the oxygen afforded by the water, that it passes to the state of phosphate of iron.

34. The native tungstate of iron, of which I have spoken at the article of tungsten, may be reckoned among the saline iron ores, since it is a combination of the tungstic acid and the oxide of this metal, mixed in fact, or rather in part saturated with oxide of manganese. It was formerly called *Wolfram* from two German words, which signify the *foam of the wolf*. It was at different periods taken for an arsenical tin-ore, a mixture of manganese, iron, and tin, for a schorl, for a basalt charged with iron, &c. &c. Messrs. D'Elhuyar, Spanish chemists, were the first who discovered that it is a true tungstate of iron. This salt is of a brownish black, in irregular masses, or crystallized in hexahedral prisms, terminating in tetrahedral pyramids, with angles truncated. It is brilliant, and almost metallic, in its foliated fracture; its powder is reddish brown; it is very

very heavy; its specific gravity is 6,835; it is nearly infusible alone, but flows very well with three or four times its weight of pot-ash, which forms a soluble alkaline tungstate, and leaves the oxide of manganese and iron separate. It is also attacked by the muriatic acid which dissolves the iron, and separates the tungstic acid in yellow powder. Messrs. D'Elhuyar found it to be composed of 0,65 tungstic acid, 0,22 oxide of manganese, 0,13 oxide of iron. From this last result we see, that if we attend to the most abundant principles of this natural compound, the wolfram ought to be referred to the ores of tungsten, which ought at least in appearance rather to be referred to manganese than to iron; but it has been supposed that the oxide of manganese is only disseminated, or mixed, not necessary to its composition; and for this reason it was merely denominated tungstate of iron, in which it was thought that the oxide of iron saturates the tungstic acid; and since the colour of this salt, as well as its nature, its form, and its properties, have seemed to be in great part owing to the iron, in its classification, it has generally been placed among the ores of that metal. Its only, at the same time, most important use for chemists, is that it affords the tungstic acid, which it affords by the same process as the tungstate of lime, that is to say, by the successive action of muriatic acid which takes up the metallic substances, and ammonia which takes up the acid,

35. The carbonate of iron is one of the most abundant and most pure ores of this metal. In metallurgy it is frequently called *steel ore*, because it easily affords this modification of iron. It has also been called *spathose* iron, or martial, or ferruginous spar, white iron ore, because it resembles in its colour its laminae and its texture, certain calcareous spars. This ore, which is abundantly dispersed in some places, is particularly so in the Pyrennean mountains, where it is deposited in veins or thick deep strata, crystallized like carbonate of lime either in its primitive rhomb, or in the secondary forms which it assumes by the laws of diminution of the rhomboidal particles: this salt is never the pure carbonate of iron. Besides the oxide of manganese, which it so frequently contains, and which causes its colour to vary from white to fawn colour, or blue, red, or blackish-brown, or black, according to its state of oxidation, it is always mixed with carbonate of lime, which amounts, according to Bergman, to half its weight, and which Citizen Haüy very ingeniously considers as the origin of its form, absolutely in the same manner as it is of the rhomboid of gritstone of Fontainebleau: so that its accurate crystals may be considered as carbonate of lime, mixed with carbonate of iron, interposed between its rhomboidal plates, as well as the oxide of manganese. It is not, therefore, as chemists and mineralogists have formerly thought, oxide of
iron

iron immediately saturated with carbonic acid first dissolved in water, and afterwards deposited in the crystalline form, nor is it the ferruginous salt which has replaced the calcareous earth, assuming its form as if cast in a mould; but it is carbonated lime mixed with carbonate of iron, as Cronstedt formerly announced, who was the first who connected the knowledge of chemistry with the method of mineralogy. This ore has the property of becoming black by the action of fire, and affords the gaseous carbonic acid, either by distillation or by the action of acids; it becomes coloured by the action of the air, and gradually assumes a brown or black shade by the oxidation of the manganese it contains, as Bergman has proved in his excellent dissertation on the white iron ores, in which treatise the author describes the properties of manganese in so complete and so methodical a manner for the time in which he wrote, that upon an attentive perusal we are disposed to think it was written rather for the purpose of affording an account of the latter metal, than to exhibit a detail of the properties of the carbonate of iron known under the name of white iron ore. Bayen, who first analyzed the spathose iron in France, and exhibited the presence of carbonic acid, also showed as well as Rouelle the younger, that it is capable of dissolving in water charged with carbonic acid, and by that means of very exactly imitating a great number of ferruginous mineral waters,

36. A kind of oxide of iron of a blue colour has been denominated prussiate of iron, which is always of a lighter colour than the artificial Prussian blue, is found frequently in peat mosses, in earths impregnated with oxide of iron, in which vegetable and animal matters are decomposed by slow putrefaction. Bergman has admitted to this species of native false blue, properties analogous to the prussiate of iron fabricated by art. It is frequently colourless when taken out of the earth, and becomes blue by exposure to the air. It is attacked by the alkalis, in which circumstance it resembles the artificial Prussian blue; but it differs from it because the acids alter it much more strongly than they do that substance. It is not yet well understood.

37. Citizen Haüy distinguishes another species of iron ore which he denominates *quartz iron*: this is emery, a well known substance, much used in grinding the hardest stones. He considers it as a particular combination between the particles of quartz and those of iron, and not as a simple mixture, because it is harder than quartz; which would not be the case if the two substances were only mixed. It appears that this property depends on the black oxide of iron, which is well known to possess extreme hardness, so that it cannot be acted upon but with great difficulty by the best files, and that it is necessary to admit a particular combination between iron and quartz to explain this
pro-

property. It is to this species, which may be considered as a mixture, in which, the force of aggregation has condensed the particles of quartz and iron, that we must refer all the other mixtures of iron in different states of oxide with sands, alumine, carbonate of lime under the form of powder or gravel, the ferruginous black, red, or yellow sand.

38. Hence according to the method I have exposed in this sketch of the natural history of iron, we may refer the numerous varieties of the ores of this metal to fifteen principal species; namely,

- a.* Native iron.
- b.* Arseniated iron.
- c.* Carburet of iron.
- d.* Sulphuret of iron.
- e.* Arseniated sulphuret of iron.
- f.* Black oxide of iron.
- g.* Pyrocite oxidule of iron.
- h.* Oligist oxidule of iron.
- i.* Yellow or red oxide of iron.
- k.* Sulphate of iron.
- l.* Phosphate of iron.
- m.* Tungstate of iron.
- n.* Carbonate of iron.
- o.* Prussiate of iron.
- p.* Quartzose iron.

To all the varieties comprised in each species, we must add, not as iron ores, but as a kind of appendages to those ores, the stones sufficiently charged with this metal in the form of

of black oxide to be attracted by the magnet, or to be magnets themselves, such as the trapps and certain species of hard and sonorous serpentine. We may also consider a great part of the volcanic lavas as substances sufficiently rich in iron to be compared with the ores of this metal.

D. Assay and Metallurgy.

39. THE number and the different nature of the ores of iron I have described, require particular methods or processes for analyzing them. Nevertheless, it has almost constantly been usual to treat them in a general manner in the assays in the dry way. The iron ores are first roasted in order to deprive them of sulphur, or to render them brittle and pulverulent; for it is easy to see, that with respect to their analysis, they may in general be considered either as containing sulphur, or as being simple oxides, or as being loaded with acid. When the acid is volatile it escapes, like the sulphur, during the roasting; when it is fixed, the ores, which contain it, are not used for extracting the metal, but they are merely reserved for certain particular uses. When the ore is desulphurated, deprived of its acid, or divided by the action of the fire, nothing more is required than to obtain the metal by fusion, which separates the portion of gangue which it contains, and deprives it of the oxygen with which it may be more or less charged

charged. For this purpose, it is mixed with charcoal and saline fluxes, such as borax, the alkalis, glass, or muriate of soda. The additions vary in the different processes which authors of chemistry have pointed out, the principle of which must be here shown.

40. Bergman directs us to put the ore, roasted or not roasted, according to its nature and particular qualities, more especially the carbonates of iron or white sparlike ores, into a crucible, lined with half an inch depth of charcoal powder at the bottom, and one eighth of an inch at the sides; to cover them with calcined borax; to lute another crucible over them, and to expose them to complete fusion by the heat of a forge.

Citizen Guyton has recommended for this operation, which is always difficult, a kind of flux, that afforded him the greatest success. He advises the use of a mixture of eight parts of pounded glass, one part of calcined borax, and half a part of charcoal; two parts, or at most three, of this flux is to be taken, if the ore be very pure, to one of the ore; the mixture is put into a crucible, lined with clay and charcoal powder to the thickness of one inch, with a crucible luted on; this vessel is then to be heated by a very violent forge for half an hour. He makes this assay twice, namely, with the roasted ore, and the ore which is not roasted, of which he takes not more than three grains. In this manner a button of pure and ductile iron is obtained, of which the weight indicates the quantity of metal

metal contained in the ore under examination.

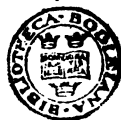
Mr. Kirwan, in his mineralogy, gives another process extracted from Crell's annals, to assay the argillaceous and filiceous iron ore, that is to say, the oxides of iron mixed with clay and filix. Four parts of the ore are taken with 1,25 parts of quick-lime, 1,25 of fluete of lime, one of powdered charcoal, and four parts of decrepitated muriate of soda. When the whole is well mixed, it is put into a crucible, lined with charcoal, to which a cover is luted; and when dry it is placed in a forge, and a moderate heat applied for a quarter of an hour, and the strongest heat for three quarters of an hour. If flaked lime be used, the weight of this ingredient must be doubled. The calcareous iron ores are treated in the same manner, by substituting twice the weight of calcareous fluete instead of the lime. The sulphureous ores are assayed after the roasting by treating in the same manner four parts with two parts of lime, two of fluete of lime, one-third of charcoal, and four parts of decrepitated muriate of soda. Care must be taken in this process by fusion, to agitate the crucible a little, in order to collect the metal.

41. The assays in the dry way, as here described, do not indicate the nature of the metal, or the alloys they can afford. They only give the quantity of iron. But iron ores may also contain manganese, and it is important to be able to ascertain its presence. The following is pointed out by Bergman, as the best process in

the dry way for this purpose. A small quantity must be heated to whiteness in a crucible, and upon this five times its weight of purified nitre is to be thrown, taking care that neither charcoal nor ashes enter into the crucible. When the mixture is cooled, the upper part of the crucible will be covered with a greenish or blueish crust, if the ore contain manganese. This is nothing more than an indication which affords no knowledge of the proportion of this brittle metal; and this, according to the remark of Citizen Vauquelin, is capable of producing an erroneous conclusion, because the alkali alone, the oxide, of the iron, or the crucible, may produce a green colour without containing manganese. But we cannot obtain this knowledge by the dry way, it can only be afforded by the humid docimasy.

The same chemist also gives a simple and easy method to determine the nature of the brittle iron, called red short, or cold short. He proposes to fuse the metal obtained from the first process, with one-fourth of its weight of good malleable iron, in a lined and well-covered crucible; if the iron thus treated is brittle, when cold, the ore which affords it will give cold short iron. If, on the contrary, the alloyed iron breaks under the hammer, when heated the ore will give only red short iron. It is very evident, that all these results are mere approximations, and can only afford indications or signs.

42. The assays which Bergman has proposed, by means of acids, or in the humid way, are true analyses, much more exact than the processes before described, and afford a certain knowledge of the nature and proportion of the component parts of iron ores; the general method he points out for the ferruginous oxides, supposing that they do not contain much earth or stony matter, is to dissolve them in muriatic acid, and precipitate them by means of the prussiate of alkali. I have not yet spoken of the prussic acid, because it is the product of a particular decomposition of organic substances, concerning which, I cannot treat but in the succeeding sections of this work. But it will suffice to state, in this place, in order to afford a clear comprehension of Bergman's process, that in the prussiates the alkali is saturated by a substance, which iron dissolved in an acid takes from it, while it yields its acid, and with which substance the oxide of the iron forms a beautiful blue colour, known under the name of Prussian blue, which is not only an indication of iron, but may also serve to determine its proportion. This precipitate is collected, washed, dried, and weighed. Its weight divided by six, and deducting also four hundredth parts for a portion of this metal, which always exists in the prussiate, gives the proportion of the iron contained in the ore with considerable exactness. In case this ore contains at the same time manganese or



zinc, which is very frequent as to the first of these metals, and not quite so frequent for the second, the following is the method of Bergman to ascertain their existence and proportion. Prussian blue precipitated from the muriatic solution is calcined to redness; then treated by the nitric acid, which takes up only oxide of zinc, when this is carried off new nitric acid is poured, with a little sugar or flour, on the residue; and by this second treatment the oxide of manganese is separated if present; the remainder is afterwards to be dissolved in muriatic acid. It is merely oxide of iron, and is to be precipitated by the carbonate of soda. After washing and drying, its weight is to be found, whence by deducting the proportion of carbonic acid which it contains, the quantity of iron in the state of oxide is known. Two hundred and twenty-five parts of this precipitate represent one hundred parts of iron. This method of separating the three metals in oxides, might be applied to all the ores of iron, if it were exact. But Citizen Vauquelin, in his analysis of steels, has shown that it is very faulty, and that Bergman often took iron for manganese.

43. The white iron ores or carbonates of iron, mixed with the carbonate of lime, are to be treated according to the method of the same chemist, by heating them first considerably, in order to drive off the carbonic acid and water, and to determine the weight of these substances. The lime is in the next place taken away by the

nitric acid, which does not act upon the oxide of iron, but which is to be left until the acid acquires a yellow colour. The calcareous earth is precipitated by soda. The undissolved metallic portion is afterwards treated as before mentioned. Rinman thought that the specific gravity of these ores is to the iron they contain in one hundred parts, as four to five.

Iron ores containing sulphur, alumine, or stony matters, are also very easily analyzed by the muriatic acid. If this acid does not act sufficiently upon the sulphurets, its action must be assisted by a little nitric acid. If the gangue be not soluble, which is the case when it is of a quartzose nature, it will be found after the separation of the oxide of iron. If it be aluminous or calcareous, it is precipitated after the iron, which is separated alone by the prussiate, leaving the pure earths dissolved in the acid.

44. With regard to the native salts of iron, such as the sulphate, the phosphate, and the tungstate, it must be remarked, that the latter is assayed and known, and the analysis performed in the same manner as with regard to the tungstate of lime. The sulphate is well known by its taste, and is in other respects so easy to analyze, as we shall see in the history of this artificial salt, that we need not in this place speak of the method of examining it. The phosphate of iron, which has not hitherto been found, excepting when mixed with the yellow or brown oxides of iron, is very distinct, and well characterized by its property

property of precipitating from its acid solutions in a white powder by mere repose. I shall presently speak of it more at length. The quartzose iron is somewhat difficult of treatment, nevertheless it does not resist the long-continued action of acids any more than ferruginous sands and the different species of ochres.

45. The treatment of iron ore, in the large way, is one of the most admirable operations of metallurgy. These ores are in general the most refractory, the most difficult to treat, those which require the greatest fire and the best furnaces. In general this treatment varies according to the state and nature of the iron in its ores. Some require no previous preparation before reduction and fusion; others must be pounded and washed, and sometimes even roasted, in order to render them more brittle and fusible. The hematites, the bog-ores, the earthy ores in masses, in grains, in pisolites, and in oolites, are in general fused in the midst of charcoal. The furnaces for this fusion are from twelve to thirteen metres or yards in height, and are constructed with very refractory bricks. Their cavity is the figure of two quadrilateral pyramids, or quadrilateral long cones, the points of which are directed upward and downward, and the bases meet at about half the height of the furnace. The widest part, or the place of this meeting is called the stage. Towards the bottom of this vast furnace an aperture is made for the purpose of drawing out the cast iron, but which is kept closed

closed with earth, while the ore is reduced and fused. To this aperture, without the furnace, there is a correspondent triangular channel in the ground for the purpose of receiving the fused metal. The process is commenced by throwing some lighted brushwood into the furnace, upon which charcoal of wood or pit-coal of a dry and fusible nature, is thrown. In the midst of this charcoal, and almost mixed with it, is put the ore, to which afterwards are added, some fluxes of the most common kind, and the most easy to be procured. It is commonly the compact of lime-stone or carbonate of lime, which we call *castine*, and sometimes the argillaceous stones are preferred, which are distinguished by the name of *arbue*. The whole of what is thus thrown into the furnace is covered with a thick stratum of charcoal which rises to the upper aperture of the furnace. The fusion is promoted by urging the fire as strongly as possible, by compressed air forced by means of bellows moved by water or the vapour of water received in a steam engine. This last instrument which possesses great power has been established in the works of Creusot near Autun, and is called the blowing machine. The oxide of iron is reduced and flows in the metallic form through the coal by means of which it was heated. At the same time the stony matters or earths which accompany the oxide, or which are added as a flux, become vitrified, and favor the fusion of the iron
which,

which commences in the wide or hottest part of the furnace near the stage. The metal is collected in the lower part of the furnace which has a slope towards the opening I have mentioned. When the fusion is very perfect, the aperture at the bottom of the furnace is opened by a bar of iron, and the metallic matter flows out in a very fluid state into a channel or receptacle which it gradually fills. After the metal flows, in a mass of various degrees of softness, ductility or fusion, the vitrified substance which forms the slag, and becomes fixed into an opaque, grey, green, whitish, bluish, or even yellowish and brown glass, according to the nature of the ore, and strength of the fire. The workmen frequently form a judgment of the state of their operation, and the nature of the metal by the properties of this slag, which supposes on their part a long series of observations on all the differences it presents, compared with the different circumstances which accompany its formation. This relation between the slag, and the nature of the metal, which is observed in the high furnaces must require (in order that it may be known with accuracy) connected experiments, and an analysis of all the varieties which this slag presents. No chemist has yet attempted this analysis.

46. The metal thus reduced, and cast in the triangular channel, in which it congeals into a large mass of the same form, is called by metallurgists

tallurgists' crude iron, 'cast iron. It is not yet a true iron. In this first state when it comes out of the smelting furnace, it is not ductile, but harsh and brittle, and on that account cannot be applied to any of the uses of iron properly so called, which in the arts, as well as in metallurgy, is carefully distinguished from iron by the names I have here pointed out. Metallurgists and chemists have long entertained systematic and erroneous opinions of the metal thus cast, and the causes of its differences from bar iron. Some have thought, and several still continue to think that its great fusibility, brittleness, excessive hardness, granulated texture resembling that of the brittle metals, depend on the portions of a greater or less quantity of the vitrified scoria or slag which remains united with the iron. Chemists who are aware from their own experiments that a substance fused into glass cannot unite to a metal, have entertained very different notions respecting the nature of crude iron. Some, with Brandt, have thought that it owed its qualities to arsenic; others supposed that zinc constantly remaining united with this metal was the true source of its properties; and others have attributed them to manganese. But as no positive experiment had proved the generality of the presence of any one of these three metals, or their constant existence in the different kinds of crude iron, the most accurate chemists have concluded that cast iron is impure

pure iron, not yet completely or perfectly reduced containing in some measure a portion of oxide interspersed between its parts. Nevertheless this last assertion was also in contradiction to the accurate notions of chemistry, because it was well known that an oxide cannot in any manner remain combined with the metal which afforded it. Bergman therefore adopted another opinion respecting the nature of cast iron; he attributed its properties to the presence of a particular metal which he named *federite*. It was soon proved to be a combination of phosphorus and iron, and in truth exists in many cast irons, whether this substance do originally rise from the bog-ores, or whether it may have been afforded, as frequently happens, by certain species of pit-coal with which some smelting furnaces are fed. But though the presence of this phosphoret of iron is indubitable in many cast irons, and contributes to render them brittle, it is sufficient to observe there are some which do not contain it, in order to prevent its being constantly assumed, as the general cause of the properties of the metal in this state of crude iron. It becomes necessary to discover the more general and constant cause in all the different kinds of cast iron. This valuable discovery was owing to three French philosophers who were jointly employed in this research. Citizens Vandermon, Monge, and Berthollet, found, by well conducted experiments, and by availing themselves

felves at the same time of all those which had been made before them, particularly the results of Bergman in his analysis of iron, that crude iron is metallic iron united with a certain proportion of oxygen, and combined at the same time with carbon, and that the differences which it presents depend on the relative proportion of these three matters. Their exact and clear results have obviated every difficulty which had before embarrassed the history of this useful substance, and clearly explained all the obscurities which were formed in the different processes of the preparation and working of the various ores of iron.

47. Metallurgists carefully distinguish various species or rather varieties of cast iron, particularly four, known under the name of white crude iron, grey crude iron, black crude iron, and spotted crude iron.

A. The white crude iron very easily distinguishable by its brilliant colour, its coarse grain, its great brittleness, and its resemblance to the brittle metals formerly called semi-metals, is in general the worst, and the least tenacious of all the irons. It contains the largest portion of oxygen, or approaches most to the state of ore in oxide. It usually contains much phosphoret of iron, and cannot be applied except for casting pieces intended neither to resist pressure nor blows, but for remaining in one place; such as the backs of chimneys.

B. The

B. The grey crude iron which occupies the middle species between the white and the black, owes its colour to a greater proportion of carbon, and less phosphoret of iron. It frequently contains no portion whatever of this last compound which causes the brittleness of the preceding variety, and of the iron it produces: the texture of the grey crude iron is close, with little brilliancy, and its grain very fine. It is easily filed and turned. This crude iron is in general of the best quality; it breaks with difficulty, and possesses tenacity and resistance; is little disposed to change, is softer than most of the other crude irons, and is therefore advantageously used for casting many instruments intended to resist weight, percussion, extension, or pressure such as wheel-work, flys, ship-cannon and artillery.

C. The black crude iron differs from the preceding in containing much more carbon, to which it owes its colour. Its blackness arises from the employment of too great a quantity of coal in the smelting, and the long time which the ore has remained in contact with an inflammable body. It would be steel if the oxygen it contains were carried off. It is therefore very proper to be converted into that compound. It is very fusible, but capable of breaking into splinters by a blow, almost in the same manner as glass, particularly when it is exposed to sudden and great variations of temperature. For these reasons it is employed
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only in uses where the resistance is little or none, in the construction of pieces of little value in their application.

D. The spotted iron, so called because it exhibits many blackish parts in its fracture which are more or less extended upon the grey or whitish ground, is a mixture of white or grey crude iron, with the black crude iron disseminated irregularly in the mass. It participates in the properties of both and is produced by unequal fusion or too sudden cooling.

The well known nature of crude iron, in general presents it as being iron slightly oxidized, and more or less carbonated, and this difference between it and iron easily explains the properties which characterize it. The presence of oxygen shows why it afforded Bergman, in his ingenious assays, a perceptibly less quantity of hydrogen gas than iron itself; why it is much less alterable by air and by water; why in proportion as it is subjected to successive fusions, particularly in reverberatory furnaces, as is practised more especially for casting pieces of artillery, large rollers, flies, and large utensils, in general it gradually approaches to the state of iron, and gives out each time according to the duration of the fire to which it is exposed, a more or less abundant portion of true carbonate of iron, well ascertained by the three philosophers before quoted; why at such times as it is laded out by portions in order to cast it into small moulds, it leaves on the ladles which are
used

used for that purpose, a scaly brilliant coating of carbonate of iron, which is very distinguishable. A constant observation more particularly confirms this last result. It is that we frequently find in the furnaces where the ores of iron are treated to obtain cast iron, as well as in the pots where it is frequently melted, pieces of artificial carbonate of iron even in the crystallized state.

48. The ingenious art by which crude iron is converted into proper iron, immediately flows from what has been here explained. It is readily conceived that it must consist only in the separation of the oxygen and the carbon, of which the union with the iron constitutes crude or cast iron. To accomplish this purpose the cast iron intended to be refined is exposed to an elevated temperature. The furnace which serves for this purpose is an iron forge somewhat hollowed, upon which a mass of crude iron is put and surrounded on all sides by charcoal. The twyer of a pair of bellows throws a great quantity of air with more or less velocity upon this combustible. As the principal operation consists in burning the carbon contained in the crude iron at the expence of oxygen, which is at the same time united with it, and to drive off these bodies which must thus engage in combination, in the form of carbonic acid gas, it is necessary to fuse the mass, and in succession to present all its surfaces to the external part of the crude iron in such a manner, that the

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gaseous

ral steel, and the ores which afford it are called steel ores, as I have already observed.

50. The iron, refined or extracted from crude iron, by the means before pointed out, is distinguished by manufacturers and different workmen who use it, into different species, according to the properties it possesses, and the several substances it may still retain in combination. It is first distinguished as soft iron and brittle iron. The soft iron is very ductile; is easily flattened and forged without heat; is also very easy to be wrought, bended at pleasure, and fashioned into every possible form. That kind of iron which, when broke, after having been several times bended in the same place, presents in its fracture threads or fibres very manifest and perceptible, is called fibrous iron, because it resists fracture, and suffers itself to be drawn out or enlarged to a greater or less degree before it breaks. We must observe, however, that iron, which is the most fibrous in its texture, may be broken short, and by a single blow, if the stroke be very violent and sudden; whereas by striking the most brittle iron by a number of successive well-managed blows, it may be made to present the fibres and nerves in its texture. We must particularly attend to examine the grain of ore broken in the same manner, in order to obtain an exact term of comparison if we wish to acquire any precise notions respecting their differences by mere inspection. Brittle iron has a coarse grain or fracture

fracture, filled with brilliant scales nearly resembling that of the truly brittle metals. Soft iron, in its sudden fracture, exhibits only a very small close grain; and if it be bended a little before it breaks, or if it be broken by several successive blows, it presents very perceptible, and even curved fibres in its fracture.

51. Very remarkable differences are also observable in two species of iron, one of which is called cold short, and the other red short. The first, in some specimens, will break with the slightest effort, almost like glass; it manifestly owes this property to the phosphoret of iron which it contains; and we may ascertain this fact at the same time that we determine the proportion by dissolving it in diluted sulphuric acid. This solution, kept for a certain time in a conical vessel, becomes white and milky; it lets fall by degrees the phosphate of iron which the phosphoret had formed by the effect of its solution. The second of these irons forges very well by cold; but by a singular property in proportion as it is heated, it becomes brittle when at a red heat, and breaks with more or less ease, sometimes like glass, and sometimes by cracking. It is generally thought at present that this last property depends on an alloy of some foreign metals, such as manganese, and particularly arsenic. That the latter, forming a very fusible alloy, becomes soft in those parts where it is diffused or lodged between the interstices of the iron which does not undergo the same

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softening, whence the particles are separated from their mutual adherence being singularly diminished, and accordingly it breaks upon receiving a blow.

52. With regard to steel, the third very remarkable state of iron, I shall not speak of it in this place, because it is a particular combination of iron and carbon, often alloyed with phosphorus, of which the history will be best placed among the combinations of iron with combustible bodies. Besides which we are in this place to consider the chemical properties of iron properly so called, and steel cannot be treated but as one of its compounds.

E. Oxidability of Iron by the Air.

53. EVERY one knows that iron, exposed to the air is, of all the metals, that which is the most altered, is converted into rust, breaks gradually into a yellow powder, and is thus intirely destroyed, even in the largest and thickest pieces, which waste away to their centre, and at last mix with the earth, the form of which they assume. This is the reason why the oxide of this metal is so frequent and so abundant amongst fossils, and seems, by combining with all other bodies, and insinuating itself, as it were, amongst all the compounds, destined to cover and colour the whole surface of the globe. Formerly this effect was attributed to the salts contained in the air, without any real knowledge

ledge of the cause of this great alteration. Since the establishment of the pneumatic doctrine and the discoveries upon which it is founded, this phenomenon is one of the best known chemical facts. It is known that iron is, in the order of metals, the second, and immediately after manganese, with respect to its combustible property, its tendency to absorb and condense in the cold the atmospheric oxygen. Of this we have a proof equally simple and decisive. When we plunge iron wires into oxygen gas, inclosed in a small bell-glass over mercury, we see the volume of this gas diminished at the end of some days, and the iron being proportionably rusted, apparently inflated or swelled, becomes covered with a powder or fine yellowish scales, which raise themselves above its surface, which adhere but very little to the metallic layer, and which at last penetrate into its interior, if the quantity of oxygen gas be sufficient, and the contact between the two bodies continued for a sufficient length of time. A small quantity of water singularly favours this action, and we shall see hereafter for what reason. A small quantity of caloric is set free, and the temperature becomes sensibly elevated in the interior of the apparatus. The iron, whilst it thus becomes spontaneously oxidized in the cold, increases in weight in the exact proportion of that which the oxygen gas loses. The same process, when performed in well-purified azotic gas, produces nothing similar. Thus, when we

consider the action of the entire air upon iron, we see that it depends upon the oxygen gas which it contains, and that it consists in a slow combustion, the product of which is the rust which reddens this metal.

54. Formerly this spontaneous oxidation of iron in the air was employed for preparing a medicine which was called *aperitive Saffron of Mars*. Iron filings were exposed in new vessels of earth or glass to the dew of May. The ideas which the alchemists had conceived concerning the effects of this dew, though chimerical as to their cause, were not without foundation with respect to their result. It appears certain, that the water precipitated from the air by its refrigeration during the night, is sufficiently charged with oxygen, to act with a very sensible energy upon the bodies that are exposed to it. It was, therefore, by the double action of the atmospheric oxygen and of the water that this oxidation was effected. The iron thus oxidized gradually absorbed the carbonic acid of the atmosphere, and grew yellow as it became carbonate; and in fact, the rust of iron, like the ancient aperitive saffron of Mars, which is only a kind of rust, treated in close vessels, yields carbonic acid gas, and passes into the state of a black powder, which is only a real oxide, as shall soon be demonstrated. On account of this facility with which iron is oxidized, spontaneously and in the cold, by the air, men have long since endeavoured to

guard it against rusting, and preserve all its properties, in order to render its use more advantageous, and its duration more permanent. Layers of oily drying colours and varnish, an application of oil frequently renewed and constantly maintained, a coating of carburet of iron rendered more or less adherent by pressure and by the mordants, even plating of metals that are much less oxidable spontaneously, such as tin, and even of those that are more precious, as silver and gold, the standard of which is then reduced in order to serve as a preservative and defence for the iron, constitute the most certain and the most common means that have been put in practice in order to fulfil this intention.

55. The combustible property of iron increases greatly with the temperature. This metal cannot be heated in contact with the air, especially to redness, even though obscure, without its burning. When this operation is performed upon large pieces or bars of iron, they become tarnished at their surface; at first they become black; this surface afterwards raises itself, increases in volume, swells, separates from the portion of not burned iron situated under it. If we let them cool in this state, and strike them, there are detached from them blackish plates, brittle, and eager like glass, of a very close and very hard texture in their last molecules, which are called iron-scales on account of the process which is employed for obtaining them: it is on this account that the

the metallurgists, and the workmen who are well acquainted with this effect, upon which depends the very speedy destruction of the thickest iron bars of the grates, or the supports in the furnaces, generally believe that iron cannot be fused without burning it; and this is exactly the case when it is fused in contact with the air. The iron-scales, when pounded, afford a black powder attractable by the magnet. Very similar to the *oligist* oxide or oxidule, if we observe them with attention, we perceive that they have suffered a real fusion, at least to a pasty consistence; that it is to this fusion that they owe their swelling or rising; that the molecules of which they are composed have become crystallized by cooling; that their approximation renders them harder and more brittle than those of the iron were, and that if we triturate them as fine as possible, they form a brilliant black powder. The portion of iron thus burned or oxidized, has augmented in weight from 25 to 27 to the hundred of the metal. It is this which is formed, in all the operations in which iron is heated, in which it is left for a longer or shorter space of time immersed red-hot in the atmosphere, in which it is struck after having been heated to redness in order to forge or weld it,—the scales, the slag, the irregular fragments, the kind of scoria, which are so frequent in the work-shops in which this metal is treated. They must not, however, be confounded with the real scoria, better fused, burned,

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or vitrified, which are afforded in smelting, and contain earths or the ashes of pit-coal, combined with the oxide of iron by vitrification.

56. Every one has also had occasion to remark that these iron-scales, when heated for a long time in contact with the air, or exposed several times in succession to the fire, acquire a very sensible brownish-red tinge: this is a continuation of oxidation, which is much better effected when we heat to strong redness iron in filings, which, after having assumed the black colour, passes to the brown or dark red. In this state, which is obtained only by continual agitation at the same time, and at a high temperature kept up for several successive hours, the oxide of iron contains more than 0,40 of oxygen, and has the form of a powder more or less attenuated. This brown oxide was formerly called *Astringent Saffron of Mars*. The properties of this kind of oxide differ from those of the preceding, or the black oxide. We may distinguish in it two portions of oxygen, as they adhere to it with different degrees of force. The 0,25 of this principle adhere to it much more than the 0,15 to 0,20 which are added to it in the state of brown oxide; we might call the first portion oxidulating, and the second oxidating. This last may easily be taken away by metallic iron, which, by sharing this oxidating oxide, constitutes an uniform black oxide through the whole mass,

mass. It was in this manner that Citizen Vauquelin found, that by heating equal parts of iron-filings and of red oxide, we obtain, without any thing being disengaged, a total of black oxide which contains now only about 0,25 of oxygen, whilst the red oxide contained before from 0,40 to 0,49. The brown oxide of iron is not reducible by the mere action of fire, and does not suffer its oxygen to be separated from it by caloric alone.

57. All the phenomena of the oxidation of iron already indicated belong only to its slow combustion; there are, however, a great number of circumstances in which this metal burns with a rapidity and energy which represent a real deflagration, an inflammation more or less violent. When, for example, we throw iron filings into a brisk fire, they burn with a very sensible emission of sparks and decrepitation. The same circumstance takes place when we cause them to fall upon the flame of a taper, or when we project very fine filings through it. When we examine the furnaces in which these ores are melted, the forges in which the melted metal is refined, the blast-furnaces in which the cast metal is fused over again by means of reverberatories, and in which it is poured into vast moulds, the work shops in which the iron is heated in order to be forged, by striking it with reiterated strokes: we every where see this metal burn with a lively flame, and with very brilliant sparks thrown out to a great distance
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like artificial fire-works. When we cause the electric shock to pass through wires of this metal, even pretty thick ones, by means of a powerful battery, we see, as was first indicated by the Dutch professor Van Marum, that the wires inflame with noise, lose their texture and solidity, become pulverized with an explosion, and are dissipated into the air in a smoke which condenses into a powder of a blackish-brown colour. Finally, the simple art of striking fire with the steel, so ingeniously contrived for procuring fire, is founded only upon the property which this metal has even in the state of steel, of kindling and inflaming in the air; and the sparks that are obtained, are only particles of iron detached from the steel by the hard stone, subjected to such violent compression and percussion, that they are immediately heated to redness, and inflamed by the aid of the atmospheric oxygen gas: accordingly, when we collect the product of these sparks upon white paper, we obtain a black powder, each grain of which, when greatly magnified by means of a lens, exhibits a small round and hollow bullet of very brittle black oxide of iron, though still capable of being attracted by the magnet.

58. The energy and rapidity of this ardent combustion is still greatly augmented, when we plunge a red-hot iron-wire into a glass filled with oxygen gas, as was first observed by Ingenhoufs. His experiment has been varied and

and enlarged in such a manner, that it is now made one of those that present the most beautiful spectacle that can be seen. A bottle of white glass, having a bottom of copper, cemented in, a small quantity of water has been left upon its bottom: to a stopper of cork, covered at its lower side with a plate of tin, to prevent its taking fire, is attached an iron harpsichord wire, or a fine pendulum-spring, at the extremity of which a little lighted pith is fixed; the stopper is then introduced again into the neck of the bottle: the pith, being plunged in the oxygen gas, burns briskly, and heats the extremity of the wire or spring to redness; and the latter, as soon as it is heated to complete redness, fuses and burns with very brilliant and very numerous flashes and sparks. Each of these, as well as the fused and incandescent portion of iron, which falls down drop by drop from the extremity of the wire, is a small hollow sphere of fused black oxide of iron. Frequently, if the oxygen gas be sufficiently pure and in considerable abundance, the whole of the iron burns with this brilliant lustre, to the last molecule that is immersed in it. Lavoisier has ascertained that it is augmented about 0,27 in 100. The same combustion of iron may be effected by blowing through a tube, oxygen gas upon iron fused before the blow-pipe in a crucible of charcoal. An analogous phenomenon is produced without having recourse to the action of oxygen gas, either by placing

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in the flame of a taper those extremely fine iron wires, which form the bases of the smallest branches of the skeletons which women use for their caps, or by exposing iron to the focus of burning glasses which collect the solar rays; lastly, we shall see hereafter that many bodies which contain a large quantity of oxygen, and which suffer it to separate quickly, have the same property of inflaming iron, and causing it to burn with noise and sparks. It is therefore evident that this metal is in the same predicament with many combustible bodies, which have two modes of burning, the one slow and the other rapid.

F. Union with the Combustible Bodies.

59. IRON is one of the substances that combine the best with different combustible bodies, and which furnishes in its combinations the greatest number of useful compounds. However we know no immediate union of it with azote and hydrogen; though it appears that in certain circumstances hydrogen gas can dissolve and carry away with it a small quantity of iron with carbon. It is known that hydrogen even in the state of gas is capable of taking from its red oxide, the portion of oxygen which is contained in it beyond what is necessary for its black oxidation, and that it is in this manner that the contact of this gas when made hot, especially with the red oxide of iron

iron, causes it soon to return to the state of black oxide, without being ever able to take from it the portion of oxygen which is united with it in the latter state, and which adheres very strongly to the iron as I have already shown.

60. Carbon combines easily with iron, when the latter is fused or only on the point of being fused, in contact with highly-divided charcoal. When the charcoal itself absorbs a little iron, and only a tenth of its weight, it becomes less combustible than it was before; it loses the metallic brilliancy; in a word, it is carburet of iron, which is prepared artificially in a multitude of circumstances, either by strongly heating charcoal already ferruginous in close vessels, or by decomposing with a strong fire organic matters, which contain a little iron, and which, when reduced to the carbonous state, frequently exhibit in their residuum the character of carburet of iron; or, which is the most frequent process of its artificial fabrication, by fusing the iron in the midst of a heap of charcoal, part of which assumes this character, or by fusing cast-iron over again several times in succession, from which there is really separated each time a certain quantity of this compound; or by strongly heating upon iron, oils, or fats, which being reduced to coal at its surface, form upon it an adhesive layer of ferruginous carbon, capable of defending it against its own oxidation.

61. There

61. There is a second kind of combination between iron and charcoal of still much greater importance than that of the carburet of iron, by its properties and numerous uses. It is opposite to the preceding in its proportions, it is not a compound of much carbon and little iron, but on the contrary a compound of much iron and little carbon. It is known by the name of steel *chalybs*. The theory of its fabrication, which has long occupied the chemists, concerning which they have had very different opinions, according to the different degrees of the advancement of the science, from the first notions given by Aristotle and Pliny, down to Reaumur, who, in his monographic work upon this composition, approached the nearest to the truth, has at last been placed out of doubt according to the experiments of Bergman, of Reaumur, of Citizen Guyton, confirmed, studied and compared by those of Citizens Vandermonde, Monge and Berthollet. From all these researches, compared with each other, it results, that when oxygen is rapidly taken away from cast iron, without the carbon being taken away from it at the same time, or when that is restored to it which escapes from its interior, with this oxygen in the form of carbonic acid, steel is obtained, and this is what is termed *natural steel*; that in all circumstances where pure or soft iron is heated for a more or less considerable time, and to a sufficient degree to soften it well, whilst at the same time

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it is immersed in highly divided charcoal, the latter penetrates into its interior, combines layer by layer with it, and causes it to pass into the state of steel, both without and within: this is called *steel of cementation, fictitious steel*. It is generally fabricated in the following manner. Bars of iron are placed in a crucible, surrounded on all sides with pulverized charcoal, without touching each other or the sides of the crucible; this vessel is covered and luted well; it is heated in a good furnace to incandescence, during seven or eight hours. When the whole is well cooled, the charcoal is found in the same state as it was put in; the bars preserve their form and situation; they only have a few blisters, which indicate the softening of their surface and the disengagement of gas. But their interior part, exposed by the action of the file, exhibits a very different state from that in which it was before. Its grain is coarser, and more brilliant than before; it is eager and brittle; it requires to be heated and forged in order to recover its ductility, and is then more malleable than it was before. If it be plunged into cold water after having been heated to redness, it assumes a hardness which iron never acquires by the same process; if we touch it with nitric acid, it presents a black spot at the place that has been touched; in a word, it is converted into steel.

62. These

62. These are the principal properties which distinguish steel from iron. Besides those which I have just indicated in a general manner, it assumes a more lively polish and a whiter colour than the latter; it is a little heavier; it is more ductile when it has been forged; it acquires by tempering a very great degree of hardness and elasticity, as well as the sonorous quality which is exemplified in the instrument called the triangle; it is less attractable by the magnet, it receives more slowly, but preserves better than iron, the magnetic property; percussion and friction communicate it to it in a higher degree; it is not so quickly oxidized in the air; this property, indeed, like several others, it possesses in common with cast iron. When we heat it in contact with the air, with the mere annealing heat, it becomes more sensibly coloured than iron does, and passes successively through constant gradations of colour, by means of which we judge of, and even determine the species of the different annealings that are given it in the arts. Whilst at the same time it loses the hardness which the tempering had communicated to it, it passes upon the polished surfaces to the white, the yellow, the orange, the purple, the blue colour; and this last colour at length disappears to give place to the colour of water, when the strongest annealing is given to it. When steel is burned, it exhales a small blue flame, and frequently a smell of garlic: accordingly we always find by analysis a small

portion of phosphorus to be contained in it, as results from the last experiments made by Citizen Vauquelin upon the different kinds of steel compared with each other. Rinman has found it to be nearly twice as dilatible as iron by heat; cast iron resembles it in this property; it is less fusible than cast iron and more fusible than iron. It may be fused and its ductility preserved; but this cast steel is afterwards very easy to be burned by fire, and cannot be welded by the fire without some other intermediate kind of steel. It burns with red sparks and not so briskly as iron. It affords more hydrogen gas by the action of the sulphuric and muriatic acids than cast iron, and less than soft iron; and this hydrogen gas is always carbonated. In all its solution there remains a black powder which is carburet of iron, more abundant in cast steel than in that of cementation, and varying singularly in its proportions, according to the different kinds of steel that are dissolved. It is to the separation of this carburet of iron that the black spot formed upon steel by the nitric acid is to be attributed, a spot which forms a very good distinctive character for knowing steel from iron. By its detonation with nitre, and the super-oxigenated muriate of pot-ash, steel gives redder sparks than iron filings; it affords carbonic acid which may be collected in the form of gas, and by the quantity of which we may know the proportion of carbon which it contains.

63. The analysis of steel, made by Bergman, Rinman, Guyton, Berthollet and Vauquelin, besides affording to the science the general results which I have just set forth, has also proved that it requires only some thousandths of carbon in order to convert iron into steel; that we do not yet know the *minium* of carbon necessary for effecting this conversion; that the *maximum* which it easily acquires when it is too much cemented, approaches in some measure to the state of black crude iron; that the phosphorus contained in it is pretty constantly in the proportion of twice that of the carbon; that we also constantly find in it silicx and manganese; but that the influence which those bodies produce upon it is not yet known, though it be probable that they are not essential to the formation, and the nature of steel. Citizen Vauquelin has made, relative to this analysis of steel, very judicious reflexions upon the circumstance that this compound is never in a constant proportion of composition, and upon the impossibility of determining this proportion in an absolute manner. For the rest, it is easy to conceive that if it requires so small a proportion of carbon united with the iron in order to constitute it steel, the smallest variation in this proportion must give rise to some variations in the properties of the steel: so that this may be extremely different, as it actually is in the arts in which it is employed with a multitude of modifica-

tions which render it more or less valuable or useful. Tempering, whilst it hardens it, modifies it also in many ways, and renders it capable of being applied to a number of uses really different, as we may convince ourselves by surveying the different branches of art in which it is employed, and the multiplicity of processes which are followed for preparing the steels which are used in them. If we compare the diversities of state, of colour, of grain, of hardness, of tenacity, of ductility, or of brittleness, which steel acquires, with those possessed by cast and forged iron, treated differently, we shall understand still better than it has hitherto been possible to do, the remarkable property which so eminently distinguishes this metal from all others ; namely, its variety of states, which form as it were a series of metallic substances, more different from each other than some real species of metals are, which, however, are universally acknowledged to be actually different from one another.

64. Notwithstanding the multiplicity of varieties which the necessities and the delicacies of the processes of the arts oblige us to admit in steel, we, however, distinguish only three principal varieties, which, indeed, comprehend all the possible distinctions, namely,

a. The *steel of cast iron*, or *natural steel* is obtained immediately from cast iron ; it is always unequal, subject to have cracks and flaws, less hard and less brittle than the two

others; it welds better in forging: is of an inferior price, as its preparation is less expensive. It is used for making agricultural instruments, springs, and common artillery: it is that steel which approaches the nearest to the state of iron.

b. Steel of cementation, factitious or artificial steel. It presents a more equal grain in its fracture, assumes a more beautiful polish than the preceding; is more hard and more brittle; requires to be forged with more precaution: it is more perfect than the former, and is employed for all the purposes in which the properties which I have just indicated are most necessary.

c. Cast steel. This is obtained by the fusion of either of the two preceding. It never has the inflations which are found in those; and is, therefore, susceptible of receiving the finest polish. It is adapted for the fabrication of razors, of lancets, of wire-drawing machines, of flatting engines, and of jewellery. It is with this steel that all those brilliant toys are made which exhibit so much lustre, and give such a value to the workmanship. This kind of steel is the most costly of the three: the English have hitherto been almost exclusively in possession of the method of preparing it.

65. Some of the facts announced in the preceding details have shown, that phosphorus is susceptible of combining with iron. Pelletier has obtained this combination by several means. By fusing equal parts of iron in clippings and

vitreous phosphoric acid with a sixth part of the weight of the latter of pulverized charcoal, he obtained a very brittle phosphuret of iron, white in its fracture, of a striated and granulated texture, attractable by the magnet, crystallized in some points in rhomboidal prisms: this is the Siderite of Bergman, who considered it as a particular metal. This phosphorus was fused under the muffle; it left upon the cupel an oxide of iron, which had in part penetrated the vessel: it contained 0,20 of phosphorus. Pelletier obtained the same compound, by heating, without charcoal, equal parts of iron filings and glass of phosphoric acid. The iron then decomposes part of the phosphoric acid, and converts it into phosphorus, which unites with the not oxidized portion of iron, and affords a phosphate of iron in a black glass. According to him, we may likewise form phosphuret of iron by throwing phosphorus in small pieces upon iron filings heated to redness in a crucible: the iron immediately enters into fusion and absorbs the phosphorus with which it combines. A small quantity of iron is oxidized by the water which moistens the phosphorus, and of which it is impossible entirely to deprive it; and this oxide, united with a little phosphoric acid, forms a black glass which covers the phosphorated metal, and which, as a very active flux, attacks the crucible, penetrates it, and filtrates through its sides. We shall see hereafter that the phosphuret of iron may be procured easily

easily and at a small expence, by decomposing phosphate of iron by means of charcoal. It is in this manner that the bog ores of iron, which so frequently contain native phosphate of iron amongst the very abundant oxide of this metal which constitutes their base, yield, after the refining of their fused metal, an iron, brittle in the cold, and which owes this bad quality, so dangerous for the arts, to a phosphuret of iron which is united with it, which Bergman had mistaken, and considered as a particular metal, under the name of Siderite, and which in the solution of this brittle iron by the sulphuric acid, yields spontaneously, when diluted with water, a white precipitate of phosphate of iron.

66. The combination of iron with sulphur is made in several different ways. In the cold, and dry, these two bodies do not unite intimately, though they are not absolutely without action upon one another; but when we add water, this union is easily effected. A paste is made with equal parts of pulverized sulphur and fine iron filings, which are mixed well by trituration, with a sufficient quantity of water: this paste, exposed to the air, soon becomes heated, swells, cracks, exhales vapours which assume the smell of sulphurated hydrogen gas, and which frequently take fire spontaneously. Though the air contributes to this action, as Priestley has found that it was altered by this mixture, and that it lost a portion of its oxygen,
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the water is really decomposed; it is this which furnishes the largest quantity of this principle to the iron: the metal is oxidized; the sulphur is at the same time burned and converted into sulphuric acid, and the hydrogen is disengaged in the form of gas, carrying along with it a small proportion of sulphur. If the mixture does not become heated to a sufficient degree to inflame, it stops at the state of sulphuret of iron, or even in greater part of hidro-sulphurated oxide of iron, from which the acids will disengage with effervescence a large quantity of sulphurated hydrogen gas: it is even the means which several modern chemists have proposed for obtaining this gas in abundance. If the temperature be raised much higher in this mixture, if much sulphurated hydrogen gas is disengaged from it, inflammation is more especially produced; the residuum is red, and resembles calcined sulphate of iron. By lixiviating it in water, we obtain from it a small quantity of super-oxygenated sulphate of iron, of which we shall speak hereafter. It is therefore evident, that the simple mixture of sulphur and iron moistened, burns spontaneously, and tends to become sulphatized, like the natural sulphate of iron, which experiences, as I have already observed, a similar alteration, which was formerly termed *efflorescence* or *vitriolization* of pyrites. The heat, the swelling, the inflammable vapours, and the inflammation itself, which are excited in this mixture, induced Lemery,

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the father, to think that it was the cause of the combustion of volcanos. He even asserted, that he had imitated a small volcano, by burying in the earth a vessel containing sulphur and wet iron filings, which he covered with earth. The ground, according to him, heaved, cracked, vapours were exhaled; the fissures became covered with a brown or reddish powder of sublimed sulphur; sometimes even the reciprocal action of the substances went as far as the inflammation of the mixture. This experiment has long borne the name of the *Artificial Volcano* of Lemery; but Bucquet, who repeated it with care, did not obtain the same result, though there is no reason why it should not be considered as perfectly consonant to all the well-known phenomena.

67. Iron is united with sulphur by several other processes. When equal parts of these two substances, well mixed together, and in the state of powder, are heated in a crucible, they are very easily fused, in comparison with the infusibility of iron; we obtain a sulphuret of iron in grains or in fibres, of a deep grey colour, very hard, brittle, highly scintillating with the steel, which is altered but very slowly by the contact of the air and water, in its state of aggregation, but which becomes heated, burned, and reduced into red sulphate of iron by the same contact, when it has been previously pulverized. A compound nearly similar to the former is produced by passing a small rod of iron,

iron heated to incandescence through a piece or a tube of sulphur. The part of this rod which touches the sulphur is immediately fused, combines with this combustible body, and being received in small blueish drops into water, these drops become fixed into hard tears, grey in their fracture, being real sulphuret of iron analogous to the preceding. It is evident from these facts, that when bars of iron are cemented into stone, as has been proposed, by the aid of melted sulphur, they form with it a brittle sulphuret, which ought to warn us not to expose these bars afterwards to support considerable weights, lest they might break at the place of cementing. The sulphuret of iron prepared in this manner, does not exactly resemble the natural sulphuret; it does not possess its yellow colour, and especially its golden lustre and brilliancy. It is probable that this is owing either to the alumine or other matters which are combined with the sulphur and the iron in the *pyrites*, or to the mode itself of their composition, which nature seems to form by means of water, whilst art effects it only by fire. The crystallization of this artificial sulphuret of iron is likewise different from that of the natural. The oxides of iron do not combine with sulphur but with difficulty. At an intense heat, the oxide losing a portion of its oxygen, unites with the sulphur, and forms a sulphurated compound of a deeper colour than the sulphuret of
iron,

iron, and which is always covered with a black powder.

68. The alkaline sulphurets dissolve iron but very little, they dissolve the oxides of this metal better, which they cause to return to the black state, and give them a very intense green colour: it appears that this colour of the solutions of the ferruginous alkaline sulphurets is owing in a great measure to the combination of the sulphurated hydrogen with iron; for the acids which disengage or decompose this mixed combustible, which is so fugacious and so alterable, cause it quickly to disappear, and whiten these solutions in however small quantity they are added. The sulphurated hydrogen gas does not unite with iron, but it acts with great promptitude upon its oxides. At the instant that red oxide of iron is thrown into water which contains this gas in solution, the colour of the oxide is changed, it passes to a more or less deep black, and the water loses its fetid smell, if a sufficient quantity of this burned metal has been put into it. The black powder, collected and dried, emits a blue flame, and exhales the smell of sulphureous acid, when it is thrown upon ignited coals: when treated by muriatic acid, it effervesces and gives sulphurated hydrogen gas: thus it is an hidro-sulphurated oxide of iron, which is formed by the union of the oxide of iron in part reduced with the sulphurated hydrogen held in solution in the water, the smell
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of which was dissipated at the very moment of this union.

69. Iron unites with many metallic substances, and forms very useful compounds by its alloys. It combines with arsenic by fusion; it even reduces the arsenious acid when heated with it: and it results from the experiments of Wallerius, of Gellert, and of Wiegel, upon this species of alloy, that it is brittle, of a white colour, analogous to the native arseniated iron or *mispickel*, much more fusible than iron, and that it is employed for making agraffes, chains, and jewellery; on account of the lively brilliancy and the beauty of the polish which it receives. Bergman considers this alloy as the cause of the brittleness of red-short iron.

70. Nothing, or almost nothing, has hitherto been said concerning the union of iron with tungsten, molybdena, chromium, titanium, and uranium. Its alloy with cobalt has been indicated by several chemists; Wallerius, in describing it, says, that these two metals may be combined without loss, by adding to them black flux and pulverized charcoal. This alloy, according to him, is attractable by the magnet, even when it contains only one part of iron to three of cobalt; but I have already shown that a much smaller proportion of iron could render this metal attractable, and that even in its pure state it appears decidedly to possess this property. The alloy of cobalt and iron is composed

posed of very small, very close, and very hard grains, which cannot be broken without difficulty: some chemists have compared it with steel.

71. According to Cronstedt, iron unites very well with nickel, and it has so strong an attraction for the latter that he has placed it in the first rank. He also remarks, that this union is favoured by sulphur. We have seen elsewhere that this combination appeared to be so intimate and so difficult to be destroyed, to the celebrated Bergman, that he despaired of being able completely to deprive the nickel of iron, and that he was induced to believe that these two metals singularly resembled one another, and that it was possible that, as well as manganese and platina, they might be only particular modifications of the same natural substance; but the rules which this able chemist has himself established in his method of reasoning as a natural philosopher, do not permit us to adopt this opinion, since most of the properties which characterize these metallic substances are more different from each other than those in which they resemble one another, and since it has also never been practicable to convert the one into the other, or to approximate and render them perfectly similar to each other; a condition absolutely necessary in order to admit a real identity between two or more substances, as the Swedish professor has himself laid down in his valuable works.

72. The

72. The alloy of iron with manganese has not yet been examined with sufficient attention to make us well acquainted with its properties: we only know that these two metals are frequently combined together, that this union renders the iron brittle; that manganese frequently accompanies the ores of iron; that it exists in the cast and the forged iron obtained from them; that it is very difficult to separate the last portions of iron from the manganese; that this is always attractable by the magnet; and that these two metals have so much analogy with one another, that we should be tempted to consider them, with Bergman, as mere modifications of one and the same substance, if they did not, however, present differences sufficiently marked in their properties when accurately compared with each other. It is yet unknown what influence the manganese produces upon the iron in the so frequent combination which it forms with this metal, either in the state of cast or of forged iron, or in that of steel.

73. Henckel was the first who remarked that iron combines with bismuth, and forms with it a brittle alloy, attractable by the magnet, though the proportion of bismuth in it amounted to three fourths. Muschenbroeck found, by his experiments, that equal parts of iron and of bismuth united badly; that the result was a very brittle metal, unequally combined, as some parts

parts of the mass were hard and others softer. He was able to examine the tenacity of this alloy only in two cases, the one, in which an alloy of twenty parts of iron with one part of bismuth was broken by a weight of 151 pounds the other, in which a combination of four parts of iron and three of bismuth presented a metal hollow at the middle, which was broken by a weight of 35 pounds. Gellert has observed, that the bismuth combined with iron is specifically lighter than the mean indicated by the relation of the specific gravity of each of these metals in their proportions. Some modern chemists have deceived themselves by concluding, from pretended analogies between bismuth and lead, that the first of these metals ought not to be susceptible of uniting with iron. Facts and experiments must be preferred to mere reasoning.

74. Iron unites easily with antimony by fusion. This alloy, made with equal parts, is neither ductile nor attractable by the magnet; it is hard, with small facets, and flattens but very little under the hammer before it breaks; it resembles cast iron according to Wallerius. Juncker has remarked, that iron fused with half its weight of an alloy of antimony and tin, affords a very hard and very brittle metal, which burns like wood by the mediation of nitre. The alloy of iron and antimony was formerly called *martial regulus*, but it was prepared with the sulphuret of antimony. Iron
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has more attraction for sulphur than antimony has; when we heat it with the sulphuret, it decomposes it and seizes its sulphur. Chemical authors have insisted much upon this operation, and have given many processes for it, differing with respect to the proportions and the mode of performing it; they had also made it the base of many pharmaceutical preparations, which are now entirely forgotten and laid aside. The following is the process most generally adopted for this decomposition. Five parts of points of horse-shoe nails, or of soft iron in very small fragments, are heated to redness in a crucible, sixteen parts of pounded sulphuret of antimony are then thrown in; a brisk fire is immediately applied, in order to effect the fusion of the mixture which very speedily takes place. When the matter is well fused, one part of nitre in powder is thrown into the crucible: this burns a portion of the sulphuret of iron, and by the aid of its alkaline flux, facilitates the separation of the scoriæ from the antimony. The mixture when cooled, presents the latter metal well collected and pure at the bottom of the crucible. If, instead of five parts of iron to sixteen of sulphuret of antimony, we employ one half of iron, the antimony which we obtain is alloyed with iron, and formerly constituted the martial regulus. In this operation, the iron combines with the sulphur, and forms a light sulphuret which rises in scoriæ above the antimony.

mony which becomes fused and precipitated to the bottom of the crucible. When the proportion of nitre employed is augmented, the scoriæ are yellowish; and they were termed by Stahl, *succinated scoriæ*. By pulverizing them, boiling them in water and causing the insoluble powder to detonate three successive times with nitre, and then lixiviating a last time, the *aperitive antimoniated saffron of mars* of Stahl was prepared.

75. There is no combination between iron and mercury. Those chemists who had conceived great and singular expectations concerning this combination with respect to the medicinal properties towards which they have so long directed their views, have in vain endeavoured to produce it: their efforts have always proved ineffectual; and in order to form pretended combinations between these two bodies, they have been obliged to employ complicated processes and intermedia, as they themselves called them, which have given results foreign to those which they sought. Thus after the complete failure of the alchemists, Wallerius pretended to form a kind of amalgam of iron by means of the sulphate of copper, the oxide of which, restored by the iron to the metallic state, afforded him only an amalgam of copper adhering, for some time only, to the surface of the iron upon which it had deposited itself. Though in some experiments of Borrichius and Junker, iron has rusted and become brittle

tle in mercury, it is only to the water with which this metal is frequently moistened, or some extraneous body, that this alteration can be attributed. Philosophers and chemists have every day occasion to see that the instruments, the tubes, the cocks of iron and steel, which they fill, which they incessantly rub with mercury in their experiments, lose neither their properties nor their brilliancy by the contact of this fluid metal. A thousand facts prove that iron acts as powerfully upon the oxides of mercury, by depriving them of their oxygen, and reducing them to the metallic state, as it acts feebly upon the running mercury. Thus iron filings become black by trituration with the red oxide of mercury, and burn even to inflammation when they are heated with this oxide: thus iron decomposes and reduces the red and sulphurated oxide of mercury, the super-oxigenated oxide of mercury, and all the other oxidized combinations of this metal.

76. Iron unites with zinc though with difficulty; most chemists have even doubted the possibility of this alloy, and have endeavoured to assign its cause to the easy fusion and volatility of the one, compared with the extreme infusibility and fixity of the other. However Wallerius, who has insisted the most upon this diversity of properties, as the reason of the indifference of those two metals with regard to each other, has observed that after having strongly heated them together, the iron had retained

retained a little zinc, which he discovered by solutions and precipitations. It is evident that this announces a real combination between those bodies, but only in very small proportion with respect to the zinc. Malouin, in his researches concerning the latter metal, has observed that zinc applies itself, like tin, to the surface of iron by fusion, and preserves it from rusting: which indicates a combination between these two metallic substances.

77. In the experiments of all chemists, iron has always been combined with tin with difficulty. There has however been prepared from time immemorial, under the name of tin plates, a composition of tinned iron, which announces a pretty strong attraction between the two metals. In order to prepare the tinned iron, (called tin) they take iron plates carefully scoured with sand, or pulverized sand-stone, in order to remove all the impurities, and that there may remain no rust upon their surface: these are steeped for twenty-four hours in water rendered sour with bran or flour, or acidulated with a little sulphuric acid, and agitated from time to time; they are scoured in this liquid; then are wiped with linen cloths; and afterwards immersed several times, in fused tin: this metal adheres to the surface of the plates of iron which it covers all over; they are drawn out of it, and kept suspended in order to suffer the superabundant portion

of tin to run off; finally, they are rubbed with saw-dust in order to clean them; and in this manner are obtained the plates of common tin. When utensils thicker than iron plate, are to be tinned, the action of the file, and muriate of ammonia are substituted instead of the bran and acid. Most chemists consider the composition of this iron as a simple tinning, or mere covering of tin applied upon the iron. Others however have remarked, that the whole thickness of the plate is whiter in the inside than iron is, and that it is softer and more malleable than the latter metal in its pure state, whence they have concluded that an interior penetration and an intimate alloy was effected.

Muschenbroeck and Wallerius, whilst they announce the difficulty of alloying those two metals with each other, have however obtained a real alloy, the characters of which they have described. Muschenbroeck asserts that this alloyed metal was very hard, difficult to be filed, of the colour of iron, very brittle, and that he was not able to estimate its consistence or tenacity. Wallerius has described it as a grey alloy, slightly ductile, attracted by the magnet, when composed of two parts tin, and one of iron. It has been generally agreed that iron renders tin harder, more difficult to be fused and more sonorous. It is on account of these properties that some persons have proposed to add iron to tin, in order to form

form a much more solid, and much more adhesive tinning for copper.

Bergman has made considerably numerous experiments, and obtained several interesting results relative to the alloy of iron and tin. He then wished to ascertain the differences or the analogies that might exist between this alloy, and the matter which he had extracted from cold-short iron, brittle in the cold, which he had believed to be a particular metal, and designated by the name of *Siderite*, but which has since been ascertained to be phosphuret of iron. By covering tin with iron filings in a crucible, the rest of which was filled with charcoal and well closed, and heating this apparatus with the fire of a forge for half an hour, he constantly obtained two distinct metallic alloys, answering to the weight of the two metals which he had employed. These two buttons were two separate alloys, the one of iron united with a little tin, the other of tin retaining a little iron. The extremes of these two metallic combinations, or the points of their reciprocal saturation were tin, containing a twenty-second of its weight of iron, and iron saturated with half its weight of tin; those at least, the properties of which he has carefully described. The tin containing $\frac{1}{22}$ of iron was very malleable, capable of being cut with a knife, though a little impaired in its brilliancy, more hard, affording with the fusible phosphates a brown glass less fusible, less combina-

ble with lead and tin, blacking and leaving an insoluble powder with the nitric acid. Tin containing only two hundredths and a half of iron, was still attractable by the magnet, and blackened in its oxidation. Iron saturated with half its weight of tin, presents properties modified by the latter metal: this alloy is slightly malleable, it is not capable of being cut with the knife, it unites only with great difficulty with mercury, it is with great difficulty fusible with the phosphates, it constantly emits in this fusion brilliant stellated sparks, which is never done either by iron or by tin alone. However, when by the addition of iron we have obtained an alloy with 0,11 of tin, this alloy is still very well characterized by the stellated brilliant sparks, which are emitted from the midst of the phosphate when it is fused before the blow-pipe; it has also the property of precipitating the solution of gold, and tinging it with a brown colour. Bergman concluded from these experiments, that the different alloys of iron and tin which he had obtained differed from the siderite: and though he had not yet found in this manner what that body was, he had found at least what it was not; a kind of discovery which being almost equally valuable, and often equally difficult to be made with that of the exact nature of a compound, certainly reveals the inquirer from the path of error, and conducts him insensibly nearer to the path of truth.

78. Iron cannot combine with lead by fusion. All chemists have observed that when the two metals are fused, the iron swims at the top of the lead, and constantly remains without uniting with it. Juncker even endeavoured to explain this phenomenon by the thickness and consistence of the particles of the lead, and by the lightness of those of the iron. Muschenbroeck, however, has described the properties of an alloy of one part of iron with three parts and a quarter of lead. He says, that a parallelopipedon of this alloy, of a tenth of an inch, required 225 pounds to break it. He adds, that an alloy, of ten parts of iron with one of lead, has a specific weight equal to 4,250: there is some error in this respect in the experiments of the Dutch philosopher Gellert, who, of all the systematic chemists, has most studied the reciprocal combinations of metals: he observes, that iron, not being able to unite with lead, may serve, by virtue of this property, to separate lead from almost all the other metals, provided, however, that the metal from which we wish to separate the lead, have less attraction for it than for the iron. Macquer remarked, in the same sense, that lead might serve as an intermedium for separating iron from the other metals with which lead can unite by preference; we shall see a well-marked instance in the history of silver, which is purified from iron by its fusion with lead.

G. Action upon Water and the Oxides.

79. I HAVE already remarked upon a former occasion, (No. 59.) that the red oxide of iron was in part decomposed by hydrogen gas, but that the black oxide was never altered by this combustible body. I have insisted upon the different attraction which exists between oxygen and the black oxide of iron; it must be recollected that the first portion of oxygen which unites with iron, adheres to it much more strongly than the last. It is in this difference of attraction that the manner in which this metal acts upon water consists. A multitude of observations proves how alterable it is by this liquid, and with what facility it is rusted and burned by its contact. The discoveries of Citizens Monge and Lavoisier concerning the nature of water, of which I have so often spoken, have shown from whence this action of the water proceeds; and the alteration itself which it causes iron to undergo, has become in the hands of the latter of these celebrated philosophers, an ingenious means for deducing from thence the compound nature of water, and proving it to contain oxygen: I have also announced that the history of this metal, so interesting in every respect, is connected with the most important epochas of the revolutions of the sciences, and that it has greatly contributed, by its excellent properties, to the establishment of the pneumatic doctrine.

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To this generality of the action of iron upon water, it is necessary here to subjoin the exposition of the phenomena which it presents, according to the different circumstances which accompany it, and the different processes by which it has been made to take place.

80. When iron filings are put with water under a bell-glass filled with mercury, and the apparatus exposed to a temperature exceeding fifteen degrees, it soon becomes filled with small bubbles, which are seen at first as if attached to the particles of the iron; gradually the bubbles, which become larger and more numerous, collect above the water and the iron, and cause the mercury to descend by the volume which they occupy. This action continues for a long time, and the iron is found at last changed into a very black powder, more voluminous than the iron from which it proceeded, was at first; the water, if it had been taken only in small quantity, is much diminished, and the gas which is collected is hydrogen gas. Lavoisier, to whom we owe this fine experiment, found that the iron had increased in weight, and that by adding this augmentation to the weight of the hydrogen gas obtained, we have precisely that of the water which was deficient. The iron burned in this manner by water, never becomes yellow or reddish, as long as it is guarded against the contact of the air, but as soon as it is exposed to this contact, and is moistened at the same time, it passes into the yellow of rust, by gradually

dually absorbing a somewhat larger quantity of oxygen, and especially of carbonic acid.

81. Lemery had made, by a similar process, a preparation of iron, which he believed to be only a simple division or attenuation of the metal, and which he called *martial Ethiops*, on account of its black colour. He put iron filings at the bottom of an oblong vessel filled with water; he agitated this metal from time to time in the supernatant water, constantly guarding it very carefully against the contact of the air, and assiduously removing that portion which, sometimes swimming at the top, quickly assumes there the character of rust or ochre. In some weeks, or some months, the whole of the filings was thus converted into *Ethiops*. In the persuasion, which long prevailed amongst the chemists, that this was only a real division of the iron, they industriously sought means for rendering it more easy and effectual, and diminished the length of time which was required for obtaining this preparation. Rouelle had advised the use of the agitators of La Garaie, in order to favour and multiply the contact between the water and the iron; others had remarked, that by adding to the water a little nitric acid, sulphuric acid, or even acid of vinegar, a large quantity was quickly formed of this powder, which is nothing else than black oxide of iron: some obtained it by reducing red oxide of iron, with the addition of oil, in a crucible; others by distilling rust of iron in an open retort. Some, relying always upon the action of the water, and believing

lieving that when prepared in any other way than with this liquid, the ethiops could not have the requisite qualities, returned to its use; and it was found that by making a paste of iron filings with water, and leaving it for some days exposed to the air, it became heated, swelled, cracked, oxidized into the yellow compound, and afterwards, by simple calcination in a crucible, became a magnificent and abundant ethiops. In this latter process, precisely the same thing is done as when the carbonate of iron or rust is heated; and the iron is always oxidized by the water, which yields to it only the portion of oxygen requisite for its oxidation in the black state. Thus, even in Lemery's method of operating, hydrogen gas was disengaged, which gradually escaped in very small bubbles, and diffused its very distinguishable odour in the places where this operation is performed. We have a very strong proof that the preparation of Lemery, or any other similar one, is only an oxidation of the iron, effected with the aid of the oxygen of the water, not only in the reduction of the red oxide, which passes only into the black, by the action of hydrogen gas, but also in the interesting experiment of Citizen Vauquelin, who, by heating in a retort or a crucible, equal parts of red oxide and of filings of iron, reduced the whole mixture into black oxide, thus causing the iron to share the portion of oxygen contained in the red oxide beyond what was required for its black oxidation.

Citizen

Citizen Monnet has asserted, that in all cases in which water is left in contact with iron, it dissolves a little of it, in its pure state, and contracts a very perceptible ferruginous taste.

82. The decomposition of water by means of iron takes place much more rapidly, when we raise the temperature of these two bodies, and especially when we place water in the state of vapour and red-hot iron in contact with each other. It was in this manner that Lavoisier confirmed the fine discovery of the nature of water. I have described this operation elsewhere: I must here only repeat that at the moment when the water in the state of vapour touches the inner surface of a red-hot tube of iron, a large quantity of hydrogen gas is disengaged, the water disappears, the iron is burned, oxidized black, softens, swells equally throughout its whole surface, in such a manner that its interior cavity becomes diminished, remaining, nevertheless, cylindrical. When this surface of iron is oxidized in such a manner that the water passes through the tube without suffering alteration, after letting the apparatus cool completely, we find, on weighing it, in the sum of the weight of the hydrogen gas, and of the augmentation of the tube, the total quantity of the water that has disappeared. The interior part of the tube presents a dilated, black, brilliant, lamellated, brittle layer, which, when reduced into powder, is real black oxide of iron.

iron. The same result is obtained by causing water in the state of vapour to pass through a tube of porcelain, into which plates of iron have been introduced; and this is the process at present employed in France for obtaining the hydrogen gas necessary for the distention of aerostatic machines. This beautiful experiment explains a multitude of phenomena which were unintelligible previous to the discovery of the decomposition of water. It shows us why red-hot iron plunged into water produces an effervescence and an ebullition, accompanied with a hissing noise, which is the more considerable in proportion as the iron is hotter; why cast-iron, in the state of fusion, produces, by the contact of water, dangerous explosions, as has been observed in founderies, where great care is taken to render the moulds extremely dry; why a great number of acids, in dissolving iron, disengage a more or less considerable proportion of hydrogen gas by favouring the decomposition of the water; why, when we heat wet or moist iron filings in close vessels, we obtain hydrogen gas, and the filings become black. It is to be observed, that the cast metal has not the same action upon water as the pure iron has, since it already contains a certain proportion of oxygen, which greatly diminishes its attraction for that principle: it is on this account that cast iron is employed with great advantage, even for works under water, and that the cast iron cylinders, which incessantly contain water in
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the state of vapour in steam engines, do not suffer alteration; whereas, pure iron, if employed for these purposes, would soon be oxidized and destroyed. Red-hot steel, on the contrary, decomposes water very rapidly, and it does not differ from iron in the products of this decomposition, except in the circumstance that it affords a little carbonic acid gas mixed with the hydrogen gas, on account of the carbon which it contains.

83. The great attraction for oxygen which all the facts hitherto adduced, show to exist in iron, must prove that this metal has the property of decomposing most of the metallic oxides: accordingly, when iron filings are heated with most of the other oxidized metals, the latter yield to the former their oxygen, which burns it, whilst they pass again into the metallic state. The less attraction the metals have for the principle of combustion, the more easily they suffer it to be taken from them by the iron, which absorbs it with the greater force and promptitude. This absorption may be so powerful as to produce inflammation of the iron. Only zinc and manganese, instead of yielding oxygen to iron, are capable of decomposing its oxides, and reducing it either to the metallic state, or to a state very nearly approaching the metallic. We shall see hereafter that iron serves, by virtue of this property, for precipitating several metals from their solutions, and enabling us to obtain them in their
natural

natural state. In these cases, the iron first seizes their oxygen, and in proportion as they are disoxygenated, they separate from the acids with the metallic lustre, and the oxide of iron which is formed, unites with the acid in their place.

H. *Action upon the Acids.*

84. THERE is no metal more oxidable and more susceptible of uniting with the acids than iron ; and at the same time there is none whose power of uniting with the acids, and remaining united with them in permanent solution, is more limited. The action of the acids upon iron, or of iron upon the acids, is one of the branches of chemistry which, as it presents the most remarkable facts and phenomena to the observer, has been most conspicuously illustrated by the French pneumatic doctrine. Previous to its establishment, every thing relative to this subject was vague and arbitrary ; the facts were, if I may use the expression, so many mysteries, or entirely undetermined problems. This profound obscurity has been succeeded by the happiest light ; and applications the most perspicuous, and at the same time the most brilliant, as well as the most methodical concatenation of all the phenomena have flowed from the bases of the modern theory as from a pure and prolific source : and the theory itself has also received great improvements.

85. The

85. The concentrated sulphuric acid has scarcely any action upon iron in the cold. When we heat it upon this metal, it suffers a decomposition proportionate to the temperature to which it is raised, and to its continuance. At first sulphureous acid gas is disengaged : if we continue the action of the fire till the mixture is reduced to dryness by distillation, we obtain sublimed sulphur, and there remains in the retort a white or reddish mass, according to the degree of heat that has been applied, but which never dissolves except partially in water, because it is the sulphate of iron decomposed. If, instead of concentrated sulphuric acid, we throw upon iron filings this acid, diluted with two or three parts of water, a quick and strong effervescence takes place ; a large quantity of hydrogen gas is disengaged, which is sometimes a little carbonated, when the iron employed contains carbon : steel, for example not only yields a hydrogen gas of this kind, but there is also separated from it and precipitated to the bottom of the acid a black powder, consisting of carburet of iron, which was first discovered by Bergman, and has since been determined with much greater exactness by Citizens Berthollet and Vauquelin. Accordingly, when this experiment is made with the view of obtaining hydrogen gas, especially in order to fill aerostatic machines, we ought to choose very pure and very soft iron, and to reject steel. The cast metal, which is much less soluble in the sulphuric

phuric acid than iron is, yields less hydrogen gas than this metal, because, being already united with a portion of oxygen, the iron which is contained in it does not require to decompose so much water in order to arrive at the point of oxidation necessary for its solution in the acid. It is not difficult to conceive, that if sulphuret of iron be employed, the hydrogen gas which is disengaged will be sulphurated. It is likewise almost superfluous here to remark, that the hydrogen gas obtained in this experiment is the product of the decomposition of the water, favoured and rendered very active by the pre-disposing attraction which the sulphuric acid exercises upon the iron, which is otherwise so susceptible of oxidation, and that it is on account of this pre-disposing attraction that this metal decomposes the water upon the first contact, whereas, if it attacked it alone, it would decompose it but very slowly under the temperature of ignition, as has been seen above. It is upon this production of hydrogen gas that an ancient experiment is founded, which was frequently performed in the laboratories of chemistry, before the existence of this gas and the art of collecting it was known; an experiment, the theory of which was then explained by the matter of fire become free, or the phlogiston which was supposed to be disengaged from the iron. A matrafs of strong glass was chosen, into which were put diluted sulphuric acid and iron: at the moment of their mutual action

and effervescence, the neck of the matrafs was stopped with the hand, which was pressed upon it pretty strongly; after the pressure had been applied for some moments, the hand was removed, and a lighted taper or piece of paper approached to the orifice of this neck: suddenly, there was excited an inflammation and sonorous detonation, on account of the mixture of the hydrogen gas with the portion of air existing in the matrafs, both being compressed by the pressure of the hand. The form and the contraction of the orifice of the vessel, the obstacle which it opposed to the dilatation and the sudden condensation of the gases by the effect of their inflammation, were the cause of the fulmination which was afforded in this experiment: it was not even free from danger; the apparatus was frequently broken when the gas had been compressed for too great a length of time, and when the vessel was not very strong. It could be repeated several times successively, on account of the large quantity of hydrogen gas which continues to be disengaged till the acid is saturated with the iron which is dissolved, and on account of the air, which being precipitated in the matrafs by reason of the vacuum produced by the first inflammation, forms in it the detonating mixture.

86. In proportion as this strong and rapid action takes place between the iron and the water which accompanies the sulphuric acid, the iron is oxidated and gradually united with the

the acid which attracts it at the same instant in which it is formed; the action almost always ceases when the acid is far from being saturated with iron; but the addition of a little water causes it to recommence, because the water existing before this addition was employed in dissolving the sulphate of iron that is formed. The combination of the oxide of iron, and of the sulphuric acid united with water gives a green colour to the liquor, which at first is very light, but at last, especially if it be exposed to the air it resembles the brilliant and pretty deep colour of the emerald. It almost always affords crystals by cooling and repose, for this liquor is agitated and hot till the saturation of the sulphuric acid by the oxide of iron, of which it can take more than half its weight, has taken place; the crystals of sulphate of iron, are of a beautiful green colour, of a rhomboidal form, and of a very strong acrid and astringent taste. This salt is prepared in the large way, by a different process in many of the places which abound with waters that are charged with it, or with sulphurets of iron; which as has been seen above, easily burn in the air, and become converted, especially with the aid of moisture, into sulphate of iron. In such countries therefore, great heaps of sulphuret of iron are formed; they are moistened with water; the moment is seized when they have effloresced, and become covered with the salt; they are

then lixivated in water; this solution is suffered to settle, and is then evaporated, and crystallized. Some places present earths naturally impregnated with sulphuret of iron proceeding from the spontaneous combustion of pyrites; these earths require only to be lixivated in order to afford the sulphate of iron; of this kind is the earth of Bechai, near Beauvais. In other places the pyrites are strongly roasted; thus their sulphur is burned and their iron oxidized; so that after this action of the fire, nothing more remains to be done than to lixiviate them with water; finally, there are some places where the waters naturally containing this ferruginous salt in solution are evaporated. It was formerly called *vitriol*, *green vitriol*, *martial vitriol*, *Roman vitriol*, *green copperas*. This saline substance, which is of great utility in the arts, ought to be known and studied with care.

87. The sulphate of iron well purified is of a transparent green colour, of a very styptic and very strong taste; it is frequently met with in nature, and is also prepared in a direct manner in the laboratories of chemistry; its mode of crystallization is considerably varied; its primitive form is a pointed rhomboid, in which the acute angle at the summit, according to Citizen Haüy, is 70 degrees 50 minutes, and the lateral angle 100 degrees 10 minutes. The respective inclinations of its faces are 98 degrees 37 minutes on the one hand, and 81 degrees

grees 23 minutes on the other; it almost always reddens the blue colours. When heated briskly, it is liquefied by means of its water of crystallization, which constitutes as much as half its weight; it soon loses this water and dries into a grey powder, with which Digby formerly made his famous and ridiculous *sympathetic powder*. If heated more strongly, it exhales sulphureous acid gas, and assumes a red colour; in this state it was called *colcothar*: this sulphate, when calcined to redness, is in a great measure decomposed; it owes its colour to the iron highly oxidized, and separated in a great measure from the sulphuric acid from which it takes away oxygen, and which it has caused to pass into the state of sulphureous acid. It still contains a portion of iron in another state than that from which it proceeds, and which I call *super-oxygenated sulphite of iron*, in order to distinguish it from the first, the properties of which it no longer possesses; it is to its presence that the deliquescence and the acrimony of the sulphate calcined to redness is to be attributed.

88. If, instead of calcining and decomposing the sulphate of iron in an open vessel, in a crucible, we perform the same operation in a distilling apparatus, and in a good retort of stone-ware that can resist a violent fire, we obtain at first some water, a little acid, which was called *dew of vitriol*, when this salt itself bore the latter name. The receiver ought to

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be changed when this water ceases to pass, and sulphuric acid is then disengaged more and more concentrated, charged with sulphurous acid, often black, and fuming on account of the quantity of sulphurous acid which it holds in solution. The last portions of acid which are obtained only with the aid of a very violent fire, kept to the white heat for several hours, are concrete and white; they were formerly designated by the name of glacial oil of vitriol. A German chemist, Christian Bernhardt, described in 1755, the singular properties of a fuming sulphuric acid of Northausen, a small town in Lower Saxony, where much of this acid was prepared by the distillation of the sulphate of iron, as is still done in many places in Germany. He found, as well as others, that this fuming acid, distilled by a very gentle fire, afforded a white concrete volatile acid, crystallized, or deposited in crusts like certain mushrooms, which exhaled much acrid vapour in the air, in which it deliquesced which united with water, with noise, &c. Meyer, who quotes these experiments in his Essay upon *quick-lime*, attributes the properties of this salt to his hypothetical principle, the *acidum pingue* or *causticum*. I have repeated the experiments of Christian Bernhardt, and have obtained exactly the same results, which I have described in detail in the memoirs of the academy for 1785, where I have shown that the concrete and crystallized acid, obtained by the distillation, is only sulphuric acid surcharged with

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with

with sulphureous acid; that it lost a great part of the latter in the air, and by its union with water; that the *fuming oil of vitriol* of Saxony might be prepared, without the necessity of distillation, by saturating sulphuric acid to excess with sulphureous acid. When we have entirely decomposed the sulphate of iron in its distillation, an operation which alone afforded the ancient oil of vitriol, before the sulphuric acid was prepared by the combustion of sulphur, there remains a red residuum familiar to that which is obtained by the calcination of the salt in open vessels, and from which was separated by lixiviation, under the name of *sal colcothar*, or *fixed salt of vitriol*, a small quantity of super-oxygenated sulphate of iron, of which I shall soon speak; whilst this lixiviation left a red oxide of iron, which was formerly called by the improper name of mild earth of vitriol.

89. Sulphate of iron, exposed to the air, experiences a kind of alteration the cause of which was formerly unknown, but which Scheele has discovered. From the green transparent colour which this salt has when it is pure, it becomes yellow, opaque, and pulverulent at its surface. Its solution in water, which requires in the cold only twice its weight of this liquid, presents the same phenomenon in a still more marked manner; the liquor, which at first is of a beautiful transparent green colour, becomes turbid, yellow, precipitates an oxide of this colour, and

and at last even becomes red, thick, uncrySTALLIZABLE, when it remains for a long time exposed to the air, and in all cases in which it can absorb oxygen. Thus, for example, the addition of oxygenated muriatic acid, turns it yellow, and immediately precipitates it. The sulphate of iron presents the same change when it is dissolved in aerated water; and Scheele has given this process for ascertaining and appreciating the quantity of air contained in the different waters, by the proportion of precipitate produced in each water at the moment of the solution of this salt: so that the decomposition of the sulphate of iron, in all its circumstances, is owing to the absorption of oxygen and the stronger oxidation of the metal. It then partly abandons the sulphuric acid, and that which remains being still more oxidized, forms the red, or super-oxygenated sulphate of iron, which was formerly called the mother water of vitriol, because its solution always remains in a certain quantity after the crystallization of the green sulphate of iron. I shall hereafter examine the characteristic and peculiar properties of this super-oxygenated sulphate, after having explained those of the ordinary sulphate.

90. The nitric acid, particularly with the assistance of heat, changes the sulphate of iron into super-oxygenated sulphate. All the alkaline earthy substances and alkalis precipitate the oxide of this salt, and decompose it. The pure fixed alkalis and lime separate from it

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an oxide of a deep green colour, appearing almost black, and remaining of this colour if it be dried quickly in a close vessel: in the air, or when this precipitate is exposed to it in a moist state, it reddens and grows yellow very quickly, the oxidation continuing to go on. Ammonia separates from the green sulphate of iron an oxide still deeper coloured than that precipitated by fixed alkalis, and which passes yet more easily to the state of black oxide, when it is hastily dried in close vessels. The sulphurets and hidro-sulphurets precipitate the solution of green sulphate of iron in a blackish sulphurated or hidro-sulphurated oxide.

91. Most of the salts have an action more or less marked on the sulphate of iron, by which they are at the same time decomposed. The principle of these decompositions, almost all of which require the agency of fire, depends on the separation of the acid from the sulphate by the caloric. It is thus that it acts on the nitrates in particular. If equal parts of nitrate of potash and sulphate of iron be distilled in a stone retort, nitric acid is obtained at first in a weak state, afterward in the state of nitrous acid, and then sulphureous acid in very small quantity. But if we take fused nitrate of potash, and sulphate of iron calcined to yellowness, we shall have very little of acid product, consisting of two liquors, one of which, of a brown-red colour, approaching nearly to black, swims on the surface of the other, which is heavier and

and less coloured, Afterwards there passes into the neck of the retort, and into the tube fitted to it, a white, concrete, very caustic, very deliquescent matter, which dissolves in water with rapidity and effervescence, emitting a considerable quantity of red vapour; which combines with pot-ash and with soda, emitting the same vapour, and forms sulphates; in a word, which is sulphuric acid rendered concrete by the nitrous vapour, or nitrous oxide, that saturates it. The two red liquors are two different nitrous acids, which mix on agitation, and afterward form but one nitrous acid of a very deep colour. Bucquet made some singular experiments on this double nitrous product, yet little known and little examined by chemists, which he communicated to the academy of sciences. The supernatant or lighter acid, mixed with sulphuric acid, produced a brisk effervescence, and even a dangerous explosion, as all the nitrous acid was instantly converted into vapour; and the sulphuric acid assumed a concrete and crystalline form by the absorption and condensation of the nitrous oxide, which it gained from it in the explosion that took place. The person who made the experiment had his face and hands covered with drops of acid; and instantly red and inflamed pimples arose on his face, which suppurated like the pustules of the small-pox. The two nitric acids obtained in this experiment are separate merely because the second, which as the lighter and more loaded
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with nitrous oxide, swims on the other, comes over gradually, and collects slowly on its surface without mixing with it. A similar phenomenon is seen in weak fulphuric acid poured on concentrated fulphuric acid, which it covers without uniting with it; and in the muriatic acid formed at the bottom of water by the condensation of the gas, which, for the purpose of preparing this acid, is passed through tubes reaching to the bottom of the water. In the latter experiment may be observed a stratum of water saturated with the acid, more dense than the water not yet saturated that covers it, and from which it is very distinct. The agitation produced by the gas, which continues to pass over and to rise higher in the liquor, in proportion as this becomes saturated from below upward, occasions the two strata at length to disappear, as it does in the two nitrous acids that are mixed. The residuum of the distillation of sulphate of iron and nitrate of pot-ash, is a kind of ferruginous scoria, from which but very little sulphate of pot-ash can be obtained, when the mixture has been powerfully heated. Much more is procured from it when it has not been exposed to so violent a fire.

92. Muricates, that of soda in particular, are decomposed by means of sulphate of iron, in consequence of the disengagement of the fulphuric acid, which separates the muriatic acid from its base. This is one of the means of procuring gaseous muriatic acid very abundantly.

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Oxygenated muriatic acid likewise passes over, in consequence of the action of this acid on the oxide of iron; this is the reason why the operation performed with sulphate of iron produces an acid tinged yellow; and at the end even a little muriate of iron rises in the state of vapour. Sulphate of soda is left in the residuum: but it is difficult to extract, because the strong heat employed in the process has combined it with the oxide of iron into a kind of frit. The super-oxygenated muriate of pot-ash alters the nature of the sulphate of iron, and makes it pass to the super-oxygenated or red state.

93. The alkaline phosphates are decomposed by the sulphate of iron, which they decompose at the same time: phosphate of iron is precipitated, and alkaline sulphates remain in solution. The borates, particularly common borax, are decomposed by sulphate of iron. In the humid way a ferruginous borate is precipitated, and sulphate of soda remains dissolved in the supernatant fluid: in the dry way, and if the experiment be made in subliming vessels, boracic acid is obtained, sublimed and crystallized by means of the water contained in the mixture. It was in such a process that Homberg discovered that species of acid which he supposed to be produced by the vitriol, and named the *volatile narcotic salt of vitriol*, in consequence of this supposition. The alkaline carbonates, in a liquid state, decompose the
sulphate

fulphate of iron, and precipitate carbonate of iron in the form of a grey powder, which differs greatly from the precipitate afforded by pure alkalis. We must observe, that all the facts hitherto mentioned respecting fulphate of iron, prove that the oxide it contains is in the state of black oxide, or is charged with oxygen only in the proportion of 0,25, or 0,29.

94. In all that precedes on the subject of the sulphate of iron, I have shown, that this salt absorbs oxygen very greedily; that it takes it from the air, from aerated water, from nitric acid, from oxygenated muriatic acid, and particularly by the agitation of its solution in contact with air, or by evaporation in open vessels. In all these cases the sulphate of iron passes to the state of a super-oxygenated salt, of which it is important to know the different properties. This super-oxygenated salt is obtained by dissolving red oxide of iron in concentrated sulphuric acid by means of heat: it has been called a *mother-water*, because some of it always remains in the solution that has formed crystals of green sulphate of iron, and, besides the red colour which distinguishes it from the latter, it is not crystallizable like it. Chemists had already observed some difference between the properties of this *mother-water*, and those of the green crystallized sulphate of iron: they had mentioned its colour, and its thick, viscid, uncrystallizable nature. Citizen Monnet had even characterized it by the more advanced state
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of the oxidation of the iron: but we are indebted to Mr. Proust, professor of chemistry at Segovia, for a sufficient series of experiments on this salt, to determine its distinguishing characteristics. His labours, communicated to the National Institute, in Floreal, year 5, leave nothing to be desired. After having collected the principal circumstances, in which the green sulphate is converted into the red sulphate of iron, termed, by me, super-oxygenated, which circumstances I have noticed above, he observes, that there are but two sulphates of iron; that there is no intermediate state between these two species; that when the former passes from green to red through different shades, and is not yet entirely changed into super-oxygenated sulphate, it is only a mixture of the two in different proportions; that they may be separated, and their respective quantities ascertained by means of alcohol, which dissolves the super-oxygenated without touching the simple sulphate of iron; so that in this solubility of the former we have the means of obtaining them perfectly pure and separate from each other.

95. The super-oxygenated sulphate of iron never yields crystals; it has a red colour; it deposits oxide of iron in the air, and by the action of fire; it has always an excess of acid; it attracts moisture from the air; the iron which saturates it contains in it 0,48 of oxygen, while that of the preceding contains only 0,27 of this principle; it is more soluble in water than the
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the sulphate of iron; it precipitates with the earths and pure alkalis a yellow or reddish oxide, which undergoes no alteration in the air, because it can absorb no more oxygen from it; while that of the green sulphate of iron easily absorbs from it the quantity necessary to increase the 0,27 of the principle it contains, to the 0,48 which it is capable of acquiring. Thus one of the most decisive characters of the two sulphates of iron consists in their comparative precipitation by caustic alkalis: the simple, or green, affords a precipitate formed of 0,73 of iron, and 0,27 of oxygen; and the super-oxygenated sulphate furnishes one containing 0,48 of oxygen, and 0,52 of iron. Another very characteristic property of the super-oxygenated sulphate of iron is, that on adding iron to its solution it is decomposed: one part of its oxygen separates from it; the other divides with the additional iron the oxygen of which it contained a superabundance, and the solution returns to the state of common sulphate. Mr. Proust announces, that quicksilver, zinc, tin, and several other metals, have the same property of causing the super-oxygenated sulphate of iron to return to the state of simple sulphate: hidro-sulphurated water decomposes the super-oxygenated sulphate of iron, and converts it into green sulphate, while, according to this chemist, it precipitates the green sulphate of iron only in consequence of the portion of oxide of copper, which it so frequently contains.

96. Lastly,

96. Lastly, two other properties, observed by the same author, distinguish and essentially characterize the two sulphates of iron: and though they are taken from agents which have not hitherto been mentioned, I shall add them here on account of these two characteristics, to render the distinction of the two sulphates of iron more complete; but previous to resuming the subject more at large, in another section, I shall only touch on them here. Mr. Proust asserts, that galls do not change the properties of simple sulphate of iron, and that they precipitate the yellow or super-oxygenated sulphate of a very bright black: in consequence of this, on exposing to the air, while it remains wet, any piece dyed with green sulphate of iron, which has not taken a black colour in the vat, the colour grows deeper and becomes black by absorbing oxygen from the atmosphere, as ink itself does according to uniform observation.

Professor Proust has found likewise, that the alkaline prussiates, thoroughly saturated and very pure, do not change the colour of simple sulphate of iron, and that Prussian blue is obtained only from those prussiates mixed with super-oxygenated sulphate: but that there are two kinds of prussiates of iron, answering to the two kinds of sulphates; one white, with the iron of 0,27 of oxygen; the other blue, with the iron of 0,48. of this principle. Accordingly, the white prussiate of iron, which is obtained by pouring a solution of prussiate of
pot-ash

pot-ash into a solution of green sulphate of iron, passes gradually to the state of blue prussiate, by exposure to the air while it is yet moist, or by the addition of oxygenated muriatic acid. Mr. Proust further generalizes and extends the history of these two species of sulphate and prussiate of iron to several other combinations of acids with the oxide of this metal, and particularly to that of the nitric and muriatic acids.

97. The action of sulphureous acid on iron is one of those which the modern chemists have most accurately traced and appreciated in the history of metallic sulphites. Citizen Berthollet was the first who perceived that this acid was decomposed by iron, and that the portion of sulphur separated from the oxygen by the metal remained in combination with the salt formed, from which it might be precipitated by means of the sulphuric acid. The phenomena of the combination of iron with the sulphureous acid have much occupied the attention of Citizen Vauquelin and myself, in our researches on this subject: and while we have confirmed what Citizen Berthollet had already announced before us, we have added some facts, which, compared with those afforded us by several other metallic substances, have allowed us to generalize the properties of a great number of metallic sulphites, and in consequence to offer a history of them more complete than the first sketches

the oxide of manganese does; which proves, that iron has a stronger attraction for oxygen, than sulphureous acid has. Accordingly iron has been seen to decompose sulphuric acid, and convert part of it into sulphureous acid; nay more, to decompose this acid, and separate from it sulphur, by which the oxide of iron is a little fixed in its combination with this acid, since the sulphurated sulphite is less alterable by the air than the simple sulphite is. It is to be observed likewise, that the sulphites of iron, whether simple or sulphurated, yield no black with galls, or blue with prussiate of pot-ash; and that hence there can be no room to doubt, that the oxide of iron in them is not carried to so great a degree of oxidation as in the super-oxygenated sulphate of iron, or even as in the sulphate of iron mixed with a certain proportion of the latter. Cast iron yields no hydrogen gas on being dissolved in sulphureous acid; and this is a mean of separating from it with accuracy the carburet of iron, which remains in a black powder after its solution.

100. Iron decomposes nitric acid with great energy. So much nitrous gas is extracted, that a very strong red vapour is formed in the air over the vessel in which the operation is performed. The effervescence, ebullition, swelling up, and froth are considerable. The iron is oxidated to a brown red, and remains in a dry powder, when little nitric acid has been poured on fine filings. This very heavy, and
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very concentrated acid however acts much less on this metal, than when it is diluted with a certain quantity of water, which appears to be necessary for the purpose of diminishing the aggregation of the molecules of the acid, and favouring the action of the iron upon them. The ancient chemists struck with the rapidity of the reciprocal action of these two substances, and solely intent on procuring themselves a solution of iron in nitric acid more or less saturated, and above all permanent, found the means of accomplishing their purpose by putting little pieces of iron into weak nitric acid, and not allowing the acid to be saturated with it. Modern chemists, since the discovery of the gases, have thought less of producing a nitric solution of iron, than of acquiring from their mutual action a process for obtaining in abundance that species of oxide of azote, which is known by the name of *nitrous gas*. Many of them have recommended this solution for disengaging this species of elastic fluid; but the very nature of the nitrate formed in this process, its avidity for uniting with oxygen, and the great quantity of it which it is capable of absorbing, form an insurmountable obstacle to the success of this project. In fact, the nitrous gas disengaged in this case is soon followed by azote gas, which mingles with it, and renders it extremely variable; so that we can never depend on the nature of this gas. When the action is the strongest possible, not

only is the azote separated from the oxygen of the acid, but also the water united with it is decomposed; its hydrogen combines with the azote of the nitric acid, and forms ammonia, as has been seen in the solution of tin. Accordingly, when quick-lime is thrown into a thick solution, or rather the magma formed by iron and nitric acid, even after having kept it some time in close vessels, a quantity of ammoniac gas, more or less considerable, is extricated.

101. When weak nitric acid and pieces of iron are employed, we obtain a solution of a yellowish green, which soon becomes brown; most frequently indeed it is of this colour: and an excess of acid is always found in it. Stahl has remarked that on putting iron into this liquid ferruginous nitrate, the oxide that was dissolved in it is precipitated, and the iron less strongly oxidated assumes its place. On leaving the nitric solution of iron exposed to the air, or on evaporating it over the fire, a precipitation of red oxide of iron takes place. Often, when quickly evaporated, it assumes the consistence of a jelly of a reddish colour, which only in part dissolves in water, and the greater portion of which is precipitated. We can never obtain crystals of it. On heating nitrate of iron in a retort, there are expelled from it much red vapour, nitrous gas, azote gas, and water. An oxide of a very lively and bright red remains. The solution of this salt precipitated

pitated by pure pot-ash gives an oxide of a bright brown: if more alkali than is necessary to effect this precipitation be employed, a part of the oxide re-dissolves, and the liquor assumes a brown colour, much deeper than the solution possessed. Ammonia forms in it a precipitate of a very deep colour, approaching to the black oxide; and even passing completely to this state, when it is dried by a sudden heat without being in contact with air. This precipitation has been proposed for preparing the *martial ethiops*, but several of the processes described above are infinitely preferable, on account of the purity of the product they afford, and the facility with which they may be performed. Though ammonia produces a precipitate much more deeply coloured than the caustic fixed alkalis, and though it approaches the blackness of the ethiops, this is because the volatile alkali is decomposed, and decomposes the oxide, as I shall show more at large, when I come to speak of the action of the bases on iron and its oxides.

102. A precipitation, formerly considered as much more important than any of the preceding, was effected by pouring carbonate of pot-ash into the nitric solution of iron. Though Stahl has only pointed out the phenomenon of the solution which takes place in this case, and though the cause of this solution remained perfectly unknown till the discovery of the carbonic acid, that chemist recommended this

this precipitation in phytic, under the name of *alkaline tincture of steel*. To obtain it, a solution of carbonate of pot-ash in water was poured into the nitric solution of iron: an excess of the precipitant was added, and the mixture was well shaken; the precipitate was soon perceived to disappear, and the liquor to assume a deep and fine red colour. Authors have differed respecting the preparation of this tincture, or alkaline solution. While Stahl, advises a well-saturated nitric solution to be taken, several chemists on the contrary would have a solution but little loaded with iron employed. It has been found by experience, that this solution succeeds better when it is very red, than when it is pale, or merely yellowish. The true cause of the solution existing in the carbonic acid disengaged from the alkali, it is proper to choose carbonate of pot-ash well saturated, and to dilute the mixture with a certain quantity of water, which, by detaining the acid, favours the solution of the iron. This liquor, on being exposed to the air, becomes turbid, precipitates, and lets fall, particularly by the contact of the air, a considerable quantity of oxide of iron of a reddish-yellow colour, which was formerly called *Stahl's aperitive saffron of steel*. I have observed, that the carbonate of ammonia, employed to decompose nitrate of iron, likewise dissolves in great abundance the oxide it separates from it, and forms a tincture as beautiful

ful as that of Stahl, which might supply its place with many advantages in the practice of physic.

103. Nitric acid adheres very feebly to the oxide of iron, and lets it fall very easily, as I have already mentioned more than once. This acid too does not dissolve the greatly oxidated oxide of iron, and is frequently employed in chemical analyses, to burn iron completely, prevent it from being soluble, and thus favour the solution of other metallic oxides, as well as their separation from that of iron. Thus Bergman particularly has directed it to be employed in the analysis of several minerals, especially of stones, earths, and the residue of chalybeate mineral waters. Thus in the analysis of ores, in which iron is in a very advanced state of oxidation, we are directed to separate the soluble earths, or the other metallic oxides, by means of nitric acid, which does not touch the oxide of iron, but leaves it by itself; so that it may be discovered, dissolved, and its proportion known, by the help of other acids, as I shall presently show. Sulphuric acid decomposes the nitrate of iron, takes from it the oxide of this metal, and combines with it so as to form super-oxygenated sulphate of iron. It is very easy to see, by simple inspection of the nitric solution, that it contains oxide of iron highly oxidated, and much more burned than it is in the green sulphate. This is proved too by the addition of galls, which immediately form a black

a black precipitate in this solution ; and by that of prussiate of pot-ash, which changes it into a pure blue, the colour of which it is not necessary to enliven by means of other acids : and I have already remarked, that ink and Prussian blue do not usually assume the full intensity of their hues, except with highly-oxidated oxides of iron ; and that, if they have not acquired their full colour, they will obtain it only by the contact of air, or by help of the oxygenated muriatic acid. But since the nitrate of iron instantly gives either of these products, we must conclude, that the iron in it is at least oxygenated to the proportion of 0,48. This is placed beyond the reach of doubt by an observation, which Citizen Vauquelin has communicated to me, on the spontaneous action of nitric acid and oxide of iron. Concentrated nitric acid, poured on oxide of iron, arising from the decomposition of water, had been left in contact with it several months, without the appearance of any very decided action having taken place between them : the nitric acid, however, without having lost its acidity, was rendered much milder, and had a very perceptible inky taste. Citizen Vauquelin was much astonished, on stirring the liquor, which was of a brown colour, to see in it several large crystals, the least of which weighed upwards of four *grammes*. These crystals were white and transparent : but on viewing them by refraction they had a slight violet tinge, and by reflection, they appeared
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of a pearl grey, as if there were a little oxide of tin between their laminæ: their form was that of a square prism, terminated by a bevel.

This nitrate of iron was very deliquescent, and of a pungent and inky taste. On throwing it into water it became red; and its solution likewise had a tinge of this colour: it gave a red precipitate with ammonia, and with carbonate of pot-ash: with prussiate of pot-ash it instantly afforded a very beautiful Prussian blue.

These phenomena prove, that nitric acid has an affinity with the black oxide of iron: that it unites with it to saturation, when the temperature is not too high: and that this combination is capable of a crystallization of some permanence. The oxide of iron is, nevertheless, at its *maximum* of oxidation in it, since it is precipitated from it red by ammonia, and by carbonate of pot-ash, and blue by prussiate of pot-ash.

104. Notwithstanding the brisk action that takes place between iron and nitric acid, I have already mentioned, that it may be so moderated by adding a large portion of water to this acid, or by mixing but very little of it in a large quantity of water, that the metal only passes to the state of black oxide; and that this was a method, which some authors had employed for preparing the martial ethiops. 'Citizen Darcet, in a report made to the Society of Medicine in 1774, pointed out the invention

of this mode as due to Crohare, at that time an apothecary in Paris: and Dr. Ingenhoufz, who, in 1797, communicated it to a druggist at Bruffels, was no doubt ignorant, that it had been practised twenty years before in Parisian laboratories. Frederic Hoffmann proposed to employ nitrate of iron evaporated to dryness, to obtain from it, by distillation, spirit of nitre, as it was then called, in a *very strong* and *very fuming* state. It is also of consequence to the history of science, to remark here, that the solution of iron in nitric acid, gave occasion to Mayow, at the end of the seventeenth century, and to Hales, almost at the beginning of the eighteenth, to make two capital discoveries, which were not productive among their contemporaries, though, in some measure, the first gleams of that revolution, which chemistry was destined to undergo, near a century after the former of these discoveries, by the examination of elastic fluids. Mayow remarked, on making this solution in an apparatus singularly analogous to that employed by Priestly and Lavoisier near a hundred years after, that, notwithstanding the disengagement of a vapour, a condensation and perceptible diminution of the air in his apparatus took place. Hales, on exposing a sulphure of iron, or pyrites of Smeathon to the action of aqua-fortis, obtained a fluid which became red on mingling with the air; and though he did not actually distinguish the nitrous gas, it is evident, that he made the first dis-

discovery of it. Finally, some modern chemists have imagined, that iron oxidated by nitric acid, assumes the characters of a peculiar acid: but no precise fact has yet proved this assertion, and it ought to be considered only as a conjecture.

105. Iron, which does not attack or decompose the muriatic acid any more than the rest of the metallic substances, undergoes, however, a great and speedy alteration in muriatic acid gas, in consequence of the water which this gas always holds in solution. The filings of iron are first seen to grow black, and then to pass to the state of reddish oxide, often moistened with small drops of green liquor. The gas increases a little in volume, and is found mixed with hydrogen gas; a proof that the water, which was dissolved in it, has been decomposed by the iron. When the muriatic acid is entirely absorbed by the oxidized iron, the hydrogen gas, produced by this action, alone fills the jar in which this action took place. If at this period a little water be let into it, this assumes a green colour, and dissolves muriate of iron, and black oxide of this metal is found at the bottom of the solution. A little muriatic acid in a large quantity of water singularly promotes the conversion of iron into black oxide, and consequently, accelerates the formation of Lemery's martial ethiops.

106. Liquid muriatic acid attacks iron, or appears to attack it so much the more rapidly,
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in proportion as it is less dense, or less concentrated. On the first contact of these substances, a brisk effervescence takes place with much noise. This effervescence is produced by the disengagement of a great quantity of hydrogen gas, proceeding from the water with which the acid is mixed or diluted. The iron, agitated in the liquor, appears as a black powder: if it contain carbon, there remains after its solution, a little powder of very black carburet of iron. Steel even leaves in this operation, when conducted slowly, a fragment, or fragments, light and porous, of this carbonated compound: in proportion as the iron is oxidized by the water, it dissolves in the acid, and composes a green liquor, which has not the fine emerald colour of the sulphate of iron, but which is either more pale, or approaching to yellow. This solution, always acid, of a strong styptic taste, is the most permanent solution of iron that exists: it becomes least turbid, and precipitates least, by any of the oxygenating processes; yet, if left for some time in the air, or strongly heated, it turns brown, and deposits oxide of iron. The most careful evaporation, and slowest refrigeration, do not separate crystals from it. When it is brought to a simple consistence, it forms on cooling a sort of magma, in the middle of which may be perceived some rudiments of flat needled crystals, which appear to be very deliquescent. This magma melts over a gentle fire, like a kind of grease. If it be
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heated for some time, it dries, assuming a reddish rust colour: and muriatic acid exhales, which, according to the observation of Brandt, carries off with it oxide of iron. On distilling the thick muriate of iron in a stone retort with a fire gradually carried to the utmost height, we obtain at first acidulated water, and muriatic acid gas, which, being loaded with iron, is deposited in crystals in the receiver, and adheres in shining coloured laminæ to the summit of the retort. At the end of the operation iron sublimes in black oxide, which crystallizes in hexahedral laminæ, shining like polished steel, and also possessing magnetic attraction: these laminæ resemble in colour, if not in figure, the iron of Volvic and Mont d'or. It is unquestionable, that the iron does not become dis-oxidized and crystallized till it has been reduced to a state of vapour, and that oxygenated muriatic acid is formed at the same time. It is very remarkable, that the muriate of iron, when recently dissolved, affords with all the alkaline re-agents in a state of purity a precipitate, which very easily becomes black oxide. Every thing indicates, that iron is least oxidized, or most disposed to lose its oxygen, in its combination with muriatic acid.

107. This acid, however, attacks all the oxides of this metal, even the most advanced; it is recommended by all chemists for dissolving the brown red, or yellow oxides of iron which resist the action of the other acids: and from
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this property it is employed with much advantage in the analysis of earths, stones, the residue of mineral waters, and incinerated vegetable and animal substances. Experience and necessity had taught this fact to those who were in the habit of working in chemical laboratories, long before modern chemists had turned their attention to the action of the muriatic acid, and still more before the cause of this action was known. It was customary in chemical processes, in order to clean glass vessels stained with oxide of iron, which adheres to them strongly, and fouls them so that they cannot be employed for any chemical operation in that state, to pour into them a little of what was called *spirit of salt*, in other words fuming muriatic acid, to shake the vessels with this acid in them, and even heat them moderately, by which means the spots of rust were removed. Some years ago I discovered the cause of this solubility of oxides of iron in the muriatic acid. Having poured this acid a little concentrated on brown oxide of iron, insoluble in the other acids, and particularly incapable of being attacked by that of nitre, I perceived, that oxygenated muriatic acid was formed. It even appeared to me, that it was formed so powerfully and abundantly, as to propose employing this process in case of oxide of manganese being wanting. In proportion as part of the muriatic acid used passes to the state of oxygenated muriatic acid, the difoxided oxide of iron dissolves

in another portion of the muriatic acid, and forms a red muriate of iron, different from the preceding as red fulphate of iron differs from the green. There is reason to believe, that some analogous experiment led Stahl into a mistake, when he asserted, that this iron converted the muriatic acid into acid of nitre; as he may have been misled by the yellow colour and peculiar smell, which this acid acquires. The super-oxygenated muriate of iron thus formed yields with alkalis a precipitate, which can no longer be oxidized by the air, at least, in any very perceptible manner: galls and the prussiates convert it instantly into a deep black and a rich Prussian blue.

108. The phosphoric acid combines but very slowly with iron: ultimately, however, it promotes its oxidation, and forms with its oxide an insoluble salt. It is thus, probably, that it combines with it in nature, and constitutes the phosphate of iron which is found in bog-ores. The following is a striking instance of this reciprocal action in a fact observed by Citizen Vauquelin. This chemist, attentively examining some very broad and thick plates of iron, applied on the bottoms of the walls of a much frequented public arcade, observed at first with astonishment, that these pieces of iron, which were so strong, had undergone a singular alteration, particularly in the recesses of the arcade: they were yellow, reddish, rusty, swelled, unequal, rough, increased in bulk, and become so brittle,

brittle, that the slightest blow, or most moderate effort, was sufficient to break them, and to remove very thick and large fragments; so that the bars placed to support and defend the stones against the wheels of carriages, and other hard bodies, which frequently struck against them, were no longer capable of resisting their pressure, or of answering the purpose for which they were designed. The cause of this great alteration was soon perceived by Citizen Vauquelin to be owing to the urine, with which these bars of iron were continually wet, in a place where people were accustomed to stop on a natural occasion. To ascertain in what this alteration consisted, Citizen Vauquelin broke off several of these pieces, and found them of a red-brown colour within, of a lamellar grain, shining, and as it were sparry, and the numerous cavities observed in them lined with small shining crystals. On heating this rusty and crystalline iron in a crucible lined with charcoal, it melted pretty easily, and afforded a homogeneous button, brittle, of a shining and metallic grey colour, and of a very hard and close grain, exhibiting with the blow-pipe, and with acids, all the properties of phosphuret of iron. This button weighed more than half of the iron employed: it was covered with a scoria of a greenish grey and swollen enamel, which was nothing but phosphate of lime vitrified, and coloured by oxide of iron. This altered metal, therefore, was nothing but phosphate of iron,
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mixed with calcareous phosphate, and some other salts and colouring matters proceeding from human urine. Charcoal being strongly heated with this substance reduced it to phosphuret of iron, by difoxidizing the metal, and disacidifying the phosphoric acid.

This observation furnishes three useful inferences. 1st, iron should not be exposed in places incessantly receiving human urine; at least without being covered with a very thick and very solid varnish: iron plunged in urine undergoes the same change. 2dly, we should not evaporate phosphoric acid in iron vessels, which wear into holes by its action. 3dly, when phosphorus is prepared with phosphoric acid, that has been evaporated in iron vessels, or even in vessels of copper, a part of the phosphorus is lost by uniting with one or other of these metals: and accordingly the residuum after distillation often contains globules of phosphuret of iron or of copper. To the reduction of the metallic phosphates into phosphurets, when the phosphoric acid employed contains much of them, a reduction effected by the charcoal, it is that the considerable swelling of the matter appears to be owing, which is so frequently detrimental in this process. Its immediate cause is the abundance of carbonic acid formed and disengaged.

Phosphate of iron is likewise prepared by pouring solutions of alkaline phosphate into a solution of sulphate, nitrate, or muriate of iron. In this case a double charge of bases

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and acids takes place. The alkali quits the phosphoric acid for the acid which holds the iron in solution; and the oxide of this metal, being separated, unites with the phosphoric acid: thus a white precipitate of phosphate of iron is obtained. It has already been seen above, that this salt dissolved in sulphuric acid diluted with water, precipitates, at the expiration of a few hours, in a white powder, which remains long suspended in the liquor, and is totally deposited only by means of lime. It is almost superfluous to add here, that the phosphate of iron, in whatever manner prepared, uniformly possesses the property of being reducible by red-hot charcoal: so that, during their fusion, through burning charcoal, ores containing phosphate of iron must have this salt converted into a metallic phosphuret, which unites with the melted metal, and remains adherent to it; whence the product, after the finery process, is cold-short iron, in consequence of the ferruginous phosphuret, with which it is more or less loaded.

109. Liquid fluoric acid attacks iron with great violence. The brisk effervescence to which it gives rise is owing to the extrication of hydrogen gas, and the decomposition of water. The solution has an astringent and metallic taste, analogous to that of sulphate of iron: it yields no crystals by evaporation, but thickens into a kind of jelly: if it be evaporated to dryness, it becomes hard and very solid: if it be strongly heated, its acid escapes, and leaves

a fine

a fine red oxide of iron. Sulphuric acid decomposes it, and extricates its fluoric acid. The oxide of iron dissolves in this acid likewise, and gives it, according to Scheele, an aluminous taste. The alkalis and earths precipitate the fluuate of iron, and separate from it an oxide, which readily becomes black on being heated.

110. The boracic acid likewise favours the oxidation of iron by water, though very slowly: it unites also, though feebly with the oxide of this metal. This combination, however, is obtained in the form of powder, on precipitating the solution of sulphate of iron by that of neutral borate of soda, or borax to which carbonic acid is added: for this salt, naturally with an excess of soda, being employed in this state to decompose metallic solutions, affords two precipitates mixed together, one of oxide produced by the excess of soda, the other of metallic borate; and if we would obtain only the latter, it is evident, that we must first cause the excess of soda in the borax to disappear. The other properties of the borate of iron have not yet been examined.

111. The carbonic acid easily unites with the oxide of iron, as has already been seen in the history of the rust of this metal, which is nothing but a carbonate, since in proportion as the iron becomes oxidized, it readily absorbs the carbonic acid of the atmosphere. This acid, dissolved in water, if placed in contact with

iron, attacks it perceptibly, emits the smell of hydrogen gas without effervescence, and, after remaining in contact with it a few hours, is found to hold a sufficient quantity of oxide of iron in solution, to give it a pungent and somewhat styptic taste. Lane and Rouelle first discovered this solution, and examined its properties. Bergman, who has given a very accurate history of it, has remarked, that when exposed to the air it becomes covered with a pellicle, which exhibits the prismatic colours; and that it is decomposed by lime and the alkalis, while the alkaline carbonates do not effect its decomposition. The carbonate of iron, thus dissolved, turns the syrup of violets green. When the liquid is evaporated, the ferruginous salt is deposited in the form of a reddish ochre.

Nature very frequently presents us with this carbonic solution of iron in mineral waters, and of the ferruginous or *chalybeate* waters these are even the most abundant. There are countries in which we meet with them at every step, as the Department of Allier, and that of Puy-de-Dôme, in the French Republic. It was formerly supposed, that the iron was simply dissolved in the water: several chemical authors, however, maintained, that the iron in it was dissolved by sulphuric acid, though they could not demonstrate its presence. The discovery of carbonic acid, under its first name of *fixed air*, has removed all difficulties on this head. It has been found, that iron is almost always dissolved

dissolved in waters by means of this acid: that there are two kinds of chalybeate waters, one containing much carbonic acid, the other but little; that those of the first kind are pungent, acidulous, and sparkling; while the second does not exhibit these characteristics; and that both deposit their carbonate of iron by the contact of air, and in proportion as the carbonic acid, by which their solution is effected, evaporates from the water. Rouelle, the younger, discovered that the natural sparry iron, or native carbonate of iron, dissolved in water impregnated with carbonic acid, also affords a good imitation of the chalybeate mineral waters. At present these waters are fabricated by art, which not only imitates the native waters, but gives them at pleasure such a degree of mildness or strength, as answers the intention of the prescriber; so that this production of art is employed in diseases with as much utility as the native chalybeate waters.

112. In my inquiries concerning the *rust of iron*, and the aperient saffron of steel, inserted in the Collection of Chemical Memoirs, which I published in 1784, I showed, that on distilling these compounds made by means of the air, carbonic acid gas and a little water were obtained; that they were then found to be converted into black oxide of iron; that on exposing caustic fixed alkalis to the vapour, which was disengaged during this decomposition by means of heat, they were crystallized by being converted

converted into carbonates; that the same rust, distilled with muriate of ammonia, afforded ammoniacal carbonate; that therefore it was artificial carbonate of iron, absolutely of the same nature as what had been called spathose iron, or white iron ore; and that this explained the rapid production of rust, which takes place from the contact of moist air, particularly in places where there is at the same time much carbonic acid, as stables, cow-houses, and privies, as well as the deep corrosion of the largest and thickest pieces of iron.

113. The action of the metallic acids on iron, and the compounds which they form with its oxide, have not yet been examined, or at least not with sufficient care and precision, to obtain a proper knowledge of them. Scarcely any thing has been added to the first facts respecting these combinations observed by Scheele. According to this celebrated chemist, iron is attacked when digested with arsenical acid, and at length the whole solution assumes the form of a jelly. If the digestion be made in a closed matrafs, so that no air shall enter into it, the solution does not coagulate. On exposing it to the open air for a few hours, its surface becomes so solid, that the matrafs may be inverted without any part falling out. The solution, not coagulated, yielded with pot-ash a greenish-grey precipitate, from which arsenious acid was disengaged by the action of fire, and

and which left at the bottom of the retort a red oxide of iron.

One part of iron filings having been treated by distillation with four parts of concrete arsenic acid, the mixture swelled up and took fire; metallic arsenic was sublimed; and spots of a yellow brown were dispersed over the inside of the retort. We see here, that the iron powerfully attracted the oxygen from the arsenic acid, and condensed it more than it was in that acid. The arsenic acid does not precipitate iron from the solutions described above; but the arseniates and arsenites separate it in a powder of very little solubility, which becomes yellowish or reddish by the contact of air. This precipitate, fusible by a strong heat, exhales the smell of sublimed arsenic when it is melted; is changed into a black scoria, when treated with charcoal, lets a considerable quantity of arsenic evaporate; and is reduced to the state of black oxide of iron, very strongly attracted by the magnet.

114. The tungstic acid acts very little directly, and without heat, upon iron. This metal, plunged into a solution of tungstic acid by the muriatic, gives it a fine blue colour, arising from the decomposition of the tungstic acid, and its conversion into tungsten by the iron. The tungstic acid precipitates sulphate of iron in the state of a white ferruginous tungstate. Wolfram, we know, is a native tungstate of iron :
and

and the artificial tungstate of iron possesses the properties of this ore.

115. Scheele has said scarcely any thing of the combination of molybdic acid with iron. He has simply announced, that the soluble alkaline molybdates formed with the ferruginous salts a brown precipitate; and that the solution of molybdic acid became blue, when metals disposed to convert it into a metallic state were put into it.

116. Though Citizen Vauquelin, in his two memoirs on chrome, and the chromic acid, has not spoken particularly of the action of this acid on iron, it is easy to conceive, from the great disposition it has to lose the acidifying portion of oxygen, and to return from the state of an orange-coloured acid to that of a green oxide, that iron plunged into its solution must produce this effect. The chromic acid unites with the oxide of iron without decomposition, by pouring into a solution of this oxide by any acid whatever, a solution of an alkaline chromate; when we immediately obtain a precipitate of chromate of iron which is of a brown colour if the ferruginous solution were super-oxygenated. In the opposite case the precipitate is green, because the chromic acid yielding some of its oxygen to the iron, which was not saturated with it, passes to the state of green oxide.

I. *Action on the Bases and on the Salts.*

117. IRON in a metallic state has but a very feeble action on the earths and alkalis: the latter, however, in a caustic and concentrated state, favour the decomposition of water by iron, since we find hydrogen gas evolved, and since the metal at the bottom of the liquors soon assumes the very distinguishable state of black oxide, or *martial ethiops*. Notwithstanding, there is scarcely any perceptible solution of the oxide of iron thus formed in the alkaline liquors, which accelerated its formation: by long contact with the air they let fall only a slight portion of a yellowish powder, which rather coats the sides of the vessel than forms a real precipitate.

118. The brown oxides of iron concrete with the earths moistened with water. This mixture acquires great hardness in time; and it has been long observed, that cements, into the composition of which oxide of iron entered, were much more solid and durable, than those of which this oxide made no part. This is unquestionably the cause of the success obtained in the preparation of cements and mortar made with puzzolana, which are a kind of earth or fragments of volcanic productions, that have in their composition a large quantity of oxide of iron, and make very good and very solid structures under water.

water. This likewise is the reason of the utility of that species of residuum, which is called cement of the distillers of aqua fortis, and is nothing but clay burned, and condensed with oxide of iron; mixed with it in pretty large proportion by the action of fire. Bricks made with ferruginous clay, and well burned, answer the same purpose.

119. Another alteration in the oxides of iron is effected by caustic alkalis, the cause of which was is not yet clearly understood. A solution of caustic soda, or pot-ash a little concentrated, cannot be poured on red oxide of iron, particularly if the reciprocal action of these two substances be assisted by heat, without the colour of the oxide tending to become black, and without the oxides very perceptibly approaching the metallic state. The same phenomenon is produced by barites, strontian, and good quick-lime, triturated with water, and oxide of iron; the oxide becoming of a deep brown, and continuing in this state, without being rendered yellow by the contact of air, as pure oxide of iron without mixture is. In these processes does any thing take place between the oxide of iron and caustic alkalis, similar to what I have observed between this oxide and pure ammonia? as soon as these two substances are brought into contact, particularly if their action be assisted by heat, the oxide of iron loses its red colour, and passes to a deep brown, and even to a black: in this case

case a sensible effervescence is produced, and azote gas is evolved, which may be collected if the experiment be performed with a sufficient quantity of the materials. It is very evident, that here the hidrogen of the ammonia attacks the oxigen of the oxide of iron, with which it forms water, leaving the iron in the state of black oxide; while its other principle, namely azote, flies off in an elastic state: but we cannot assert the same thing of the fixed alkalis, of the nature and composition of which we are ignorant, and in which, as I have elsewhere said, even the presence of azote has not yet been proved.

120. There is another mode of combination between the earthy bases in particular, and the oxide of iron; which is that of fusion by means of a more or less powerful heat. The oxide of iron unites intimately with an earthy alkaline substance; fuses with it into a glass, to which it gives a deep brown, or a dusky green colour, or even almost a black tinge: though sometimes the glass is simply greenish. The colour of this vitrification varies indeed according to the state of the oxide of iron, its quantity, the mixtures with which it is combined, and the degree and continuance of the heat to which it is exposed. Hence the shades of a great number of reds, browns, red or brown yellows, bright or deep green, which are given to enamels, to the coatings of earthen-

ware, and porcelain, or to the different kinds of glass that are fabricated, according to the state of the oxide of iron, that enters into their composition, the proportion of it used, and the degree of heat employed.

121. Iron, like all other metallic substances, acts upon salts in consequence of the action it is capable of exerting on the acids they contain. It is thus that it decomposes the alkaline sulphates by the help of a high temperature, because it then takes oxygen from their sulphuric acid, and reduces it to the state of sulphur. I have found, that by keeping in a red heat for an hour, in a crucible well closed, one part of sulphate of pot-ash with two parts of fine iron filings, a sort of granulous scoria was obtained, black and exhibiting the prismatic colours, swelled up, of a deep green at its surface, and producing brown red spots on the crucible towards the upper part. This substance was very hard, and very difficult to cut with the file: in some interior cavities it exhibited bright hexahedral laminæ of black oxide of iron: it had an acrid and burning taste. On reducing it to powder, it exhaled a fetid smell of sulphurated hydrogen gas: though it did not attract the moisture of the air. Being lixivited with ten parts of distilled water, it afforded a green liquor of so deep a hue, that it required more than thirty additional parts of water, to give it transparency. This was a solution of hidro-sulphurated sulphate of pot-

pot-ash, containing a little iron, from which acids precipitated sulphur, and disengaged sulphurated hydrogen gas, at the same time completely destroying its colour, which appears to arise from hydro-sulphurated oxide of iron. The greater part of the matter was not dissolved in the water, but with muriatic acid yielded much sulphurated hydrogen gas. All the alkaline and earthy sulphates are capable of being decomposed in the same manner by iron strongly heated.

122. All the nitrates are likewise decomposable by iron heated red hot, or on being projected into a red-hot crucible when mixed with this metal in fine filings. The nitric acid of these salts yields its oxygen to the iron, which afterward remains burned, and almost always takes fire, and occasions the detonation of these salts: the bases of the salts are then mixed with the oxide of iron, which adheres to them more or less strongly, according to their nature. The nitrate chosen for this operation is that of pot-ash, or common nitre, as the most plentiful, and that which succeeds best in detonations. Two or three parts of this salt are accurately mixed with one part of fine iron filings, fresh, and not rusty, in a cast-iron mortar: this mixture is thrown by a little at a time into a crucible, placed in the midst of well-burning coals. At every projection a great number of brilliant sparks arise; and accordingly a similar mixture is employed in fireworks.

parts of muriate of ammonia, and one part of iron filings: this mixture was sublimed in two stone jars, placed one upon the other; there was but very little of the muriate of ammonia decomposed, and this salt was but slightly tinged with yellow by a small portion of muriate of iron which was formed. The same medicine was prepared with oxide of iron, hematites, &c. In several German pharmacopœias, equal quantities of sal ammoniac and oxide of iron or iron filings were directed to be taken: and accordingly, the *ammoniacal flowers* obtained were much higher coloured, than those of which I have spoken. They contained much more muriate of iron, which, on exposure to the air, attracted its humidity, and formed a reddish yellow, thick, and very acrid liquor, very improperly called *oil of steel*. Boerhaave, by applying alcohol to the *ammoniacal flowers of steel*, prepared a tincture greatly loaded with iron; the muriate of iron being very soluble in alcohol.

The red or yellow oxides of iron decompose the muriate of ammonia much better than iron itself. Hence, on triturating these oxides with this salt, we have a very brisk smell of ammonia: but it must be observed, that the trituration develops caloric, which begins the decomposition. It has been seen above, that ammonia decomposes the muriate of iron without heat: iron and its oxides, therefore, decompose muriate of ammonia only by the help of

an increased temperature, and a double affinity, that of oxide of iron for muriatic acid, and that of ammonia for caloric.

125. The super-oxygenated muriates burn iron with much force; but the action of super-oxygenated muriate of pot-ash alone on this metal has not yet been appreciated. If two parts of this salt be mixed with one part of very fine iron filings, the mixture is made to detonate strongly, and with a very bright red flame, by a blow, or by hard pressure; and it kindles with great force on the contact of an ignited substance. This affords one means of making an exact analysis of cast iron or of steel, by collecting the elastic fluid produced, and the metallic oxide, which are the results of this operation. The portion of muriate of pot-ash remaining after the detonation may easily be separated from the oxide by washing it. The combustion of iron and steel by the super-oxygenated muriate of pot-ash may be hereafter employed for fire-works, on account of the very brilliant flame, and the beautiful effects of the light, which accompany this rapid and instantaneous combustion.

126. We know not of any action between iron and the phosphates, fluates, borates, and carbonates, in the moist way, and without heat. This metal, however, is so easily oxidized, and has so much energy for absorbing oxygen, and saturating itself with it, that it is not difficult to conceive how it may rust very quickly in

the air, when wetted with solutions of these salts. With heat, it readily burns and combines into oxides with such of these salts as are more or less fusible and fluxive. It colours them of a brown green, or of deep and obscure hue, which afterwards attest its presence in the vitreous globules obtained in making experiments of this kind with the blow-pipe, as is customary.

K. *Uses.*

127. IN what has preceded I have already pointed out a great many of the uses of iron. In particular I have shown, that this metal, of much more real utility than gold or silver, on the one hand in consequence of its abundance, on the other on account of its numerous properties, has the incalculable as well as singular advantage over all others, of being capable of existing in a number of different states, and of possessing qualities that render it of inestimable value in each of these. In the beginning of its history I have insisted upon the great analogy, which the philosopher finds between the prosperity of nations, the perfection of human reason, and the improved state of the various arts employed on iron; particularly of those, which consist in giving it all the modifications of which it is susceptible, of having it nearly as soft and flexible as tin in one of its extremes, and in the other so hard and tenacious,

cious, that it can penetrate any substance, or that none can resist it. In the latter state all things seem to be subject to its power and dominion: it causes their figure, their consistency, their texture, and their organization to disappear. In the hands of the man who possesses the knowledge, that enables him to give it this sovereign power, it incessantly alters and modifies every thing around him; and by this alone we may judge, not only what pre-eminence over all other animals it has conferred on the human species, but what progress it must have enabled the human understanding to make. How great the difference that must exist between the savage nations to whom it is unknown, and the civilized people who have most advanced its manufacture, and multiplied its uses!

128. Though it is now decidedly known, that cobalt and nickel share its magnetic property, it is still the only metal that guides the mariner in his voyages; and it will long retain this preference, on account of its magnetic power, its abundance, the facility with which it is manufactured, and the ease with which we can in some degree multiply in it this singular property. Under this point of view the uses of iron cannot be limited, and it is impossible yet to foresee, how far they may hereafter extend.

129. If we would generalize the important and numerous services, which iron in its me-

tallic form renders to society, we shall see, that when cast it forms plates, slabs, vessels, mortars, cannon, cylinders, the bodies of pumps, flies, wheels, &c. from the immense machines, the great movements of which it directs, down to the slender nails fabricated in England, and exchanged for the wealth of India. From bridges of ample dimensions to the small thin clasps, this fusible metal, strong, hard, and almost unalterable in its first state of fusion, answers a number of purposes in social life. As iron of every description, brittle, tough, red-short, cold-short, ductile, fibrous, it supports and sustains a variety of efforts, shocks, and pressures; from the vast beams of large machines, and the bars which lock together and hold fast the stones and timber work of great edifices, to the slender threads that vibrate under the finger of the musician, or are used for making metallic stuffs. It assumes all forms, receives an immense series of modifications; it is the great mover of machines; it separates, distinguishes, and protects our dwellings; it adorns our monuments; it charms our ears; it is incessantly adding to the industry, power, and enjoyments of man; in fine, this metallic Proteus, in the state of steel of such various kinds, is employed for a thousand important uses, from the fine and delicate needle, which directs the course of the navigator, and the exquisite springs that move and regulate our watches and time-keepers; from the powerful springs, on which

our

our coaches hang and vibrate, to the ornamental trinkets that shine with such vivid lustre and high polish; from the beneficial plough, that furrows our soil, to the simple knife employed for cutting almost all ordinary substances; from those masterly performances of the engraver, which are multiplied upon metals themselves by the pressure of the coining engine, to the needle of the housewife. With reason, therefore, is it regarded as the soul of all the arts; and it employs millions of hands in civilized nations, whose genius and industry it incessantly attests, while it multiplies their enjoyments.

130. If we consider its different states in the bowels of the earth, we shall still behold it of use in various forms, almost without any previous preparation. Here it is dug up as a magnet, which is armed and fortified by the assistance of natural philosophy: there it is taken up hard, quartzose, and bearing the name of emery, to be employed, after it has been ground in mills, for wearing away and polishing the hardest and most refractory substances, under the hand and pressure of the workman. Again we extract it under the appearance of earths of a thousand different shades of colour, to enrich the painter's pallet, and soon to see it live and breathe on the canvas. In other places it is brought out of the bowels of the earth, to be cut into red pencils, to be diluted into durable mortar, or to decorate the walls of our gardens with sand of various hues.

Some.

Sometimes it is taken from the mountains with the soft, unctuous, friable, shining, and I would say at the same time almost lubricating properties, as well as great unalterableness, which are perceived in the native carburet of iron, to diminish the friction of wheels, trace lines, and drawings on paper, and cover and protect from rust implements of iron, either by simply rubbing them with its powder, or by besmearing them, being previously warmed, with a kind of ointment described by Homberg in 1699, and prepared with eight pounds of hogs lard, four ounces of camphor, and a sufficient quantity of this carburet. In the last mentioned state it serves likewise to blacken and smooth the surface of small-shot; it constitutes almost wholly the crucibles of Paffau in Saxony, and in part the coating of razor strops: it serves as a glaze to some kinds of earthenware: &c.

131. In chemistry and in physic iron is not less useful. In the preceding details, we have seen all the experiments in which it is employed, all the products it yields, and all the phenomena to which it gives rise. Physicians procure from it important remedies, and medicines of great value in the treatment of diseases. It is perhaps, the only metal, among those which have any medicinal action, that is not to be ranked in the class of poisons: it even seems, as I have already mentioned, to have a sort of analogy with the animal economy: it stimulates the organic fibres, and increases their

their movements; it perceptibly strengthens muscular energy; it excites the secretion of urine; it provokes the hemorrhoids and menstrual evacuation; it increases and accelerates the current of the blood; it enters into the circulation; unites with the vital fluid, and gives it more colour and consistency; it irritates the sides of the vessels through which it is conveyed; it has been detected in the urine of patients who have used it for some time; it contracts the fibres like astringents; it is proper in all diseases of atony and languor. It is employed chiefly levigated in a black oxide in a state of great tenuity, in artificial carbonate either dry or dissolved in water, in alkaline martial tincture, in ammoniacal flowers of steel, in oxide precipitated, and re-dissolved by carbonate of ammonia. Some of its oxides, and some of its salts, particularly the sulphate and muriate of iron, are applied externally as astringents and desiccants. In the artificial magnet, men have even sought qualities, of which, however, neither the cause nor the real effects are yet known. It has been pretended, that the magnet, applied to the skin, eased pain, quieted convulsions, excited redness, and perspiration in the part, and even rendered epileptic attacks less frequent: and it has been said, that it communicates a purgative virtue to water, in which it has been steeped for some hours. These properties, however, appear to have been attributed to iron rather by an enthusiastic imagination.

imagination than by accurate observation, particularly in diseases, which are in their own nature variable and uncertain,

ARTICLE XIX.

Of Copper.

A. History.

1. COPPER is one among the class of metals most anciently known. It appears to have been used by men in the first age of the World: at all times it has been one of the most easy to extract and manufacture; and its discovery is lost in the periods of fable. The Egyptians employed it for a variety of uses, and made of it cast figures, remarkable for their elegant form, in the remotest times of their history. The Greeks manufactured it, melted it, cast it, and employed it in various arts. With them it made the base of the celebrated compounds called Corinthian brass. The Romans likewise manufactured it in great quantity; and it has even been imagined, that the greater number of their utensils were always made with this metal, and very rarely with iron. This circumstance has been urged as a valid proof, that they knew little of iron, and were unskilful in manufacturing it. I have already shown elsewhere, that this ignorance of the arts of the Romans, and the

the opinion that they used copper only, and not iron, arise from their instruments and machines of iron having been rusted, oxidized, and gradually destroyed, in the earth in which they have been buried. The compositions of copper which the Romans fabricated after the example of the Egyptians and the Greeks, were sufficiently numerous, and destined for a variety of purposes.

2. The alchemists have employed themselves much about copper. They called it *Venus*, on account of the great facility it possesses of combining with many substances, particularly with other metals, and because of the sort of adulteration it makes in these compounds. By representing it by the emblem appropriated to gold, terminated at bottom by the sign of a cross, they considered it as formed chiefly of gold, but disguised and altered by something acrid or corrosive, which rendered it crude. According to them, the separation of this corrosive was sufficient, to obtain gold from it: whence they made a great number of trials with this view; and several have boasted, that they had succeeded in transmuting it into fine gold. The colour of this metal, which approaches nearest to gold, must naturally have suggested the opinion they entertained in this respect; and it was strengthened by the circumstances of a number of metallic combinations, in which gold assumes the colour of copper. Thus the alchemists engaged in great and laborious

laborious researches concerning this metal and it was from their books, that the first systematic writers on chemistry derived the information, which they arranged in more or less methodical order, as the science gradually arose.

3. We are no less indebted for the numerous facts, which they have furnished for explaining the properties of copper, to the mineralogists and metallurgists, on the one hand, whose numerous operations have been of much service to the systematists as well as to the pharmacologists, who, by seeking to avail themselves even of the acrimony of this metal, and to convert its venomous power into a medicinal quality, or to enchain and moderate its corrosive activity, have described a great many productions and combinations of copper. Here, as in the history of most other metals, the first and principal historians of the science of chemistry have drawn from the triple source of the alchemists, miners, and physicians, in order to compose the whole of the distinguishing characters and different compounds of copper. In spite of the great researches made concerning this metal, no author yet has written *ex professo* on copper, and comprised the whole of its properties in a monographic treatise.

4. Though in the different periods of the great revolution, which has changed the face of chemistry, we cannot find any researches concerning copper, which are immediately connected

ned with the annals of this revolution, or have served to lay the foundations of it; yet this metal holds a rank among those substances, of which the properties are better known, and the modifications have been more accurately determined, since the establishment of the pneumatic doctrine. In this class of properties accurately explained by the modern theory, we ought particularly to place its different degrees of oxidation, its solutions in acids and in ammonia, its precipitates, from the metallic state to its highest degree of oxidation, and its reduction by various processes. The labours of Citizens Berthollet and Guyton, and those of Mr. Proust, have particularly contributed to the accurate knowledge of these last mentioned facts. The knowledge of this metal is become much more complete, and far more simple, since the existence of the new discoveries. It is not necessary to observe, that the ridiculous denomination of *Venus* has been entirely rejected from scientific language, and that it is scarcely used except for some preparations employed in the arts, into which systematic and regular nomenclatures are so long before they arrive, and so late in being adopted.

B. *Physical Properties.*

5. COPPER is a very brilliant, very shining metal, of a rich appearance, and a red or rosy colour, which does not resemble that of any
2 other

other metallic substance. If gold have a resemblance to it in some compositions, it is indebted for this to the copper mixed with it; and its brightness yields to that of copper, by which it is far exceeded in this respect. Accordingly, copper was esteemed by the alchemists, who discovered in it a tinging quality, which they highly valued, and which in reality affects almost all compositions of metals, as will be seen below.

6. The density of copper is such, that its specific gravity is to that of water as 7,788 to 1,000. This gravity, however varies, according to the state of the metal: when it has only been melted and cast, it is less than when it has been hammered and forged, in which state it has the gravity I have assigned it above. On the other hand, copper after having passed through the mill, and been drawn into wire, or of which the particles are greatly compacted together, has the specific gravity of 8,878, which is an increase of about one seventh; and native crystallized copper exhibited to Citizen Haüy another mean gravity of 8,584.

7. The hardness of copper is pretty considerable: it holds almost the third rank among metals in this property. With regard to its elasticity it is nearly the same. Its ductility has led Citizen Guyton to place it in the sixth rank of metals, between tin and lead. It may

be reduced into laminæ, or leaves extremely thin, which the wind will blow away. Its tenacity likewise is pretty considerable: a copper wire a tenth of an inch in diameter supports a weight of 299 $\frac{1}{4}$ pounds without breaking. Its strength, or resistance to being broken, is estimated by Wallerius as nearly equal to that of iron. Its sonorous quality is superiour to that of iron, as may be proved by wires of the two metals of equal length and thickness.

8. Its power of conducting caloric has not been accurately ascertained, though it is known to be very great. I have mentioned its comparative degree of expansibility under the article iron. It does not melt till it is very red. Its fusibility has been estimated by Mortimer at 1450° of Fahrenheit's thermometer: and by Citizen Guyton at 27 degrees of the pyrometer of Wedgwood. When it is melted, and cast into ingot moulds, that it may cool quickly, it assumes a granulous and porous texture, which shows like a kind of *crumb (mie)* in its fracture, and is liable to exhibit many cavities and flaws in its interior parts. If it be cooled slowly, it yields crystals in quadrangular pyramids, or in octahedrons, which arise from the cube, its primitive form. At a temperature, above what is required for its fusion, it rises in vapour, and in a visible smoke, as is observed in places where this metal is cast in the large way, and in the chimneys over the furnaces.

9. Copper

9. Copper is a very good conductor of electricity and galvanism; but the order and kind of its power in this respect, compared with that of other metallic substances, has not yet been determined with precision. The acrid, and somewhat fetid smell, which pretty sensibly characterizes and distinguishes copper, is well known to every one. We are not ignorant, that rubbing the hand a little while on this metal is sufficient to impart to it this coppery odour, to which some other phenomena of the organ of smell have even been compared, particularly that of a *cold in the head*. This tenacity and communication of smell by the slightest friction, and most simple contact of the skin, prove, that the copper wears away, and attaches itself easily to this organ, and that the air, which touches or surrounds it, is incessantly dissolving a minute layer of it, which it afterward conveys in vapour to the nostrils, and the olfactory nerves. Its rough and disagreeable taste is equally known to all men, as well as its quality of being poisonous and deleterious to the animal economy. It excites vomiting, and is rejected by all animals.

C. Natural History.

10. COPPER is pretty abundantly diffused throughout nature: Germany, Sweden, and Siberia, however, are the three countries, where it has hitherto been found in the largest quantity

tity, and which furnish the most to commerce and the arts. The states of this metal in the earth are so various in their appearance, and in their physical properties, that mineralogists have singularly multiplied the species of it: some have admitted fifteen or twenty, though it is difficult to reckon nine or ten really different from each other in their nature. What they have taken for species are only varieties. The method which I have laid down, and hitherto followed in classing ores, will place this truth beyond the reach of doubt. Conformably to this method I shall announce the different states of native copper, of its mixtures with metals, of its oxides, and of its salts.

11. Native copper is met with pretty frequently in the interior parts of the earth; where it is even found very pure. It is known by its brilliancy, its red colour, its ductility, and its specific gravity. Most commonly its surface is of an obscure, dull, and brown red, on account of the slight oxidation it has experienced: sometimes it is found shining, and as if it had been burnished or polished; but this is much more rare than the preceding. Its form is frequently crystalline and regular: that of Siberia distinctly exhibits the cubic figure. Among the principal varieties of this form Citizen Haüy has distinguished the cubo-dodecahedral solid, or cube with twelve marginal facets, which, if they were prolonged till they met, would produce the rhomboidal

rhomboidal dodecahedron. Native copper is often met with in laminæ, net-work, octahedrons, herborizations, irregular grains, filaments, fern-leaves, and figures more or less resembling those of other natural productions. The copper of cementation is distinguished likewise, deposited in very flat laminæ, or very thin leaves, formed of several small grains adhering to each other, and separated from a native solution of sulphate of copper by iron, which this solution has met with in the interior of the earth. The places where native copper is most frequently observed are Siberia, Norberg in Sweden, Newfol in Hungary, Saint-Bel near Lyons. Almost all rich copper-mines contain it.

12. We yet know few natural circumstances in which copper is mixed with other metal, particularly where its proportion is such, that the species of compound may be referred to the history of copper itself. Hitherto scarcely any metal except gold and silver has been found thus united with copper: and then the quantity of those metals much exceeding that of the copper, these specimens belong more properly to their natural history. It may be said therefore, that we are yet acquainted with no real cupreous compounds, which can justly be placed here.

13. Of native combinations of copper with unmetallic combustible substances the sulphuret of copper is the only one yet existing. We do not accurately know the comparative nature,
and

and consequently the real differences and number of species of sulphureous copper ores, which it is necessary to admit, and to distinguish from each other. This is owing to the apparently great variety of these ores, either in respect of the proportions of the sulphur and copper, or of the number of other metals with which they are frequently combined. Iron is almost always united with them; frequently silver exists in them; and sometimes we find in them arsenic and antimony. As these also constitute the ores of copper most commonly wrought, and as miners distinguish them from each other into a great number of species, according to the quantity and kind of the metal they yield, the difference they require in working them, and the phenomena they exhibit in their processes; there hence arises an uncertainty and difference of method among mineralogists, as well as the very various number of these ores which they have adopted. In this vague and arbitrary state, upon which chemical analysis does not yet enable us positively to decide, I admit, with Citizen Haüy, three species of native sulphuret of copper, if not yet well determined, at least very distinct from each other; those which he has termed *pyritous copper*, *grey copper*, and *sulphurated copper*. Their characteristic properties I shall point out in succession.

14. The pyritous copper was called *cupreous pyrites*, or *yellow copper ores*, by mineralogists. It is generally considered as copper with much

iron mineralized by sulphur. It was so regarded by Cronstedt, Bergman, and Von Born, who thus brought it near to sulphuret of iron, with which we know not yet whether it may not be hereafter necessary to confound the pyritous copper ore. On this occasion Citizen Haüy asks, whether this copper ore be not a sulphuret of iron mixed with copper, and whether this latter metal do not form in it a real triple combination with sulphur and iron. Romé de Lisle, one of the most able mineralogists France ever produced, gave as the distinguishing characteristic of the cupreous pyrites, its tetrahedral figure, which in one of its varieties exhibited a truncation of its four angles, or their interception by as many triangular facets; but this left the tetrahedral figure always very conspicuous. Citizen Haüy however observes, that we sometimes find the same cupreous pyrites in the form of a very regular octahedron; and then, as this form recurs in the native sulphuret of iron, the line of demarcation between the two ores disappears, and their real difference is no longer established. The yellow colour of the pyritous copper is likewise an insufficient distinction, since it varies with the quantity of metal. This is the reason why I have adopted the name of pyritous copper, which pre-judges nothing, and which has been given to this ore by Citizen Haüy, on account of the uncertain knowledge we yet have of it. Several varieties of the pyritous ore of copper are distinguished

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on account of their colour, the *spotted* copper ore, the *peacock's-tail* ore, &c.

15. The grey copper of the same mineralogist is the *grey copper ore containing silver*, or even the *grey silver ore* of the authors who have preceded him in this career. It is the *fahlertz* of the Germans. All the miners rank it among the silver ores, on account of the quantity of this precious metal they obtain from it. This ore varies so much in the proportions of the metal it contains, that we might class it indifferently in appearance, though very distinctly for each variety, among those of antimony, or those of silver. It has some general characters, however, which has determined most mineralogists to class it with copper ores: it is of a grey colour, of little brilliancy, though metallic; its texture is tough and granular, sometimes polished laminæ, parallel to the faces of the tetrahedron, are found in it; its powder, taken off by the file, is blackish, with a red tinge; it has sometimes externally the lustre of polished steel; frequently, however, it is dull and livid. Romé de Lisse has distinguished in it fifteen varieties of figure, all dependent on the tetrahedron, which is its primitive form. From the comparison of some modern analyses, seven metallic substances are found in it, namely, copper, silver, iron, antimony, arsenic, quicksilver, and gold, united with sulphur, without reckoning a little alumine: but there is reason to believe, that most of these metals are only

accidental or accessory to the copper, the antimony, and the sulphur, the proportions of which three have been found most uniform in the different analyses compared with each other; so that, as it appears, we may consider it principally as a compound of these three substances.

Mr. Klaproth has found in the grey copper of Cremonitz the following substances and proportions :

Antimony	-	34
Copper	-	31
Silver	-	14
Sulphur	-	11
Iron	-	3

There was a loss of seven parts.

Von Born adds, that Mr. Savarese found in it gold and quicksilver.

M. Napión published in the Memoirs of the Academy of Turin, in 1791, an analysis of the grey copper of the Valley of Lanzo, from which he obtained,

Antimony	-	36,9
Copper	-	29,3
Sulphur	-	12,7
Iron	-	12,1
Arsenic	-	4,0
Alumine	-	1,1
Silver	-	0,7

The loss was 3,2.

16. The *sulphurated copper* of Citizen Haüy is the vitreous copper ore of Von Born, who gives as its characteristic the containing only copper and

and sulphur, and no iron, though Bergman asserts, that it is very rare for it not to contain a little. It is grey, of the colour of iron, slightly tinged red or blue, compact, yet capable of being cut by a knife. It is affirmed, that this ore is fusible in the flame of a candle, notwithstanding the little sulphur it contains. Von Born adds to this description of Wallerius, that this sulphurated copper is most frequently found in single pieces adhering to other species of copper ore. It has been said too, that this sulphuret of copper is frequently in separate octahedral crystals.

17. Though all the other ores of copper, of which it remains for me to speak, equally contain this metal in the state of oxide, it is not as pure oxides of this metal, that I ought to present them in my method; and to this class of native oxides of copper I can refer only two species; namely, brown oxide of copper, and green oxide of copper. The first, which Citizen Haüy calls *red oxidized copper*, which is the *red vitreous ore of copper* of de Lisle, and which Von Born designates by the name of *red carbonate of copper*, though improperly; since it dissolves in acids without effervescence, and without yielding carbonic acid gas. Its colour is a red, more or less bright: its fracture lamellated, with a metallic lustre on the surface of its laminae. It crystallizes in small, brilliant, very regular octahedrons, which may be divided parallel to their faces, or into little capillary filaments

ments of a fine red colour. Sometimes its octahedrons are coated with malachite, or green carbonate of copper. We see likewise some pieces of this ore of a greyish red, or of a blackish colour; and this led Romé de Lisle to imagine, that the grey vitreous ore of copper was only an alteration of the red vitreous copper.

18. The green oxide of copper, which Citizen Haüy calls green super-oxygenated copper, is the sand of this colour, which Dombey brought from Peru. It is mixed with fine fragments of white, grey, and reddish quartz; it contains also muriate of soda, and it is to this salt, decomposed by heat, that we owe the oxygenated muriatic acid afforded by this sand, when distilled in a retort. When thrown into the midst of flame it communicates to it a fine green colour. It is soluble in all the acids.

19. The native salts of copper may be reduced to three very distinct species; namely, the sulphate of copper, the blue carbonate of copper, and the green carbonate of copper. The first is distinguished by its figure of an oblique angled parallelopiped, which is the primitive form; by a bright blue colour, and a blueish grey powder often covering its surface; by its rough and astringent taste; and by its solubility in water. It is frequently found in solution, and this native cupreous sulphuric water affords copper, by putting into it pieces of iron. The copper thus obtained is called copper of cementation. It must be observed, that the sulphate

fulphate of copper and the fulphate of iron are the only salts which have a colour essential to their nature.

20. The blue carbonate of copper is called, in most mineralogies, *azure of copper*, *crystals of azure*, *blue chrysocolla*. It has been erroneously supposed to be formed by ammonia, or to be a simple oxide of copper. Fontana first discovered, that it contains carbonic acids. Pelletier made an accurate analysis of it, and found the following to be its nature and proportions :

Pure copper		from 66 to 70
Carbonic acid	-	18 to 20
Oxygen	-	8 to 10
Water	-	2.

Fire expels its carbonic acid, as the stronger acids likewise do. All the acids, and also ammonia, dissolve it readily : the former change it green, and the ammonia heightens the intensity of its blue colour. The crystals of azure of copper are too small to have allowed their structure to be examined. There is a variety of this blue carbonate, which is in the form of an efflorescence, or of a simple earth : it is called *mountain blue*, or *earthy blue copper*. This second variety is frequently found with some one of those of the preceding species. To this species likewise have been referred the *turquoises*, or blue fossil stones, which Reaumur has said are coloured by copper ; and the *Armenian stone*, which, Mr. Kirwan informs us,

is

is carbonate or sulphate of lime, to which copper has given a blue colour. Both these are deprived of their colour by the action of fire, when it is urged to a sufficient degree.

21. The green carbonate of copper, or super-oxygenated carbonate of copper, very distinguishable by its colour, exhibits three principal varieties: the earthy, called *mountain green*; that which is crystallized in fine brilliant needles very close together, and which is called *filky copper*; and lastly, that which deposited in the manner of stalactites, and forms *malachite*. These three varieties are nothing but the pure carbonate of copper, in which the metal is more oxidized than in the preceding ore. All three differ only in the circumstances of their formation. They equally yield carbonic acid, when acted on by fire or by stronger acids: they are easily converted into metal by charcoal, or oils, and contain much copper. They likewise afford specimens more or less prized for mineralogical collections.

D. *Affay and Metallurgy.*

22. Though at first sight it appears very easy to assay copper ores, or rather to reduce them, in the dry way, on account of the fusibility of this metal; this operation is, nevertheless, one of those, which give the least accurate results; and, if we would obtain a result on which we can depend, it requires a great number of complex processes,

processes, on account of the foreign metals, of which it is important to ascertain the number, nature, and proportions; either that we may know how to free the copper from them, if they be capable of altering it; or how to extract them, and derive from them all the advantage possible, if they be metals much more valuable than the copper itself. But the process of reduction, which we have hitherto followed, will not easily supply us with sufficient information in this respect, either to acquaint us with the composition of copper ores, or to instruct us in the means of working them with advantage.

23. In the description of the processes proper for assaying ores of copper, sufficient regard has not been paid to the difference of these ores: yet it is easy to see, that some may afford results much more certain than others. For instance, ores in the state of oxides or carbonates, when they are reduced by means of an alkaline, and coaly flux, yield almost all their copper pure and without waste; for as they contain neither sulphur, nor for the most part any other metallic substance but that which is proper to them, and require nothing from the action of the flux and the fire but the disengagement of their volatile acid, the reduction of their oxide, and the fusion of that portion of earth, or of their gangue which accompanies them, they are not liable to undergo any kind of alteration from such a flux. But it is not
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the same with sulphureous ores, of whatever nature they may be in other respects: for the sulphur they contain unites easily with the alkali of the flux, and the sulphur thus formed, dissolves a part of the metal they contain. Hence arise two inconveniences, which render that knowledge of these ores, which the process of reduction in the dry way is capable of affording, uncertain and inaccurate: one is, that the part of the copper retained and dissolved by the sulphur, diminishes the quantity of that which is obtained, even in a considerable degree; because, as will presently appear, the quantity of the alkaline flux recommended by authors is sufficiently great to dissolve much of the metal: the other consists in this, that the copper reduced, retaining with it almost all the silver, which is frequently contained in these ores, and exhibiting it in the subsequent assays, then indicates to the operator a larger proportion of this precious metal, than there really was in the entire and original ore. In fine, the reduction and fusion in the dry way cannot serve to afford an estimate of the quantity of sulphur, any more than of the foreign metals, antimony and iron, which are so frequently found in the grey or yellow sulphureous copper ores, and which give a brittle and impure copper. The description of the assay in the dry way, given by the principal writers on docimastics, will prove these assertions to the clearest conviction.

24. To make this assay, after the ore is pounded and washed, we are advised to subject it to long and repeated roastings, in order to divide it, soften it, and separate the sulphur. It is then to be fused with four times its weight of black flux, and a little muriate of soda. The metal extracted, and thus precipitated to the bottom of the crucible, is almost always more or less sulphurated, brittle, grey, or at least of a dull brown, and far from being of the fine red of copper. We are, nevertheless, recommended to fuse it with four parts of lead, and afterwards to pass this mixture through the cupel, to obtain from it the gold and silver it may contain, to determine the presence and quantity, of which is a particular object: but this operation is very difficult, and scarcely ever attended with complete success. Tillet, who was aware of the inconveniences of this process, proposed another flux, not capable of retaining the metal, which was composed of two parts of pounded glass, one part of calcined borax, and an eighth of charcoal.

25. What I have said of the defects of this reduction in the dry way, and the extreme difference there is between this inaccurate process and a true docimastic analysis, render a description of the methods of solution recommended by Bergman in his Dissertation on the humid Analysis more necessary here, than in any other place. This able chemist has varied them according to the nature and species of the ores.

ores. Native copper he has recommended to be dissolved in nitric acid. The gold, if it contain any, remains undissolved at the bottom of the menstruum, in a black powder. If it contain silver, he directs it to be precipitated by copper, which, having in fact, a stronger affinity for oxygen than silver has, immediately disoxidates this metal, and separates it in a metallic powder. As to the iron, by boiling the solution a little longer, evaporating it to dryness, and re-dissolving it, the nitrate of copper is taken up by the water, while the oxide of iron remains in a red powder without dissolving.

26. The following is the mode in which he directs sulphurets of copper to be treated. They are to be pulverized, and then boiled in five parts of concentrated sulphuric acid. The solution being evaporated to dryness, the residuum is to be washed in hot water, till the whole of the metallic salt is taken up. This solution being sufficiently diluted, a plate of copper is first to be put into it, which precipitates the silver; and then a plate of very clear iron, with which it is boiled, till nothing is any longer precipitated. The copper thus precipitated is dried by a gentle fire, not capable of promoting its oxidation, which would increase its weight. If there be any reason to apprehend, that iron is mixed with the copper, it is re-dissolved in nitric acid, and the operator proceeds with this solution in the same manner

manner as is directed for native copper. In this process, Bergman observes, the sulphur is entirely dissipated in vapour, in consequence of the violent heat employed for evaporating the sulphuric solution to dryness : but, on the one hand, the weight of the sulphur is deducible from that of the other matters obtained; on the other, a separate solution may be made of part of the same ore in nitro-muriatic acid, to separate, collect, and appreciate the sulphur by itself.

27. In speaking of ores in the state of red, blue, or green oxide, which he says are very conveniently and entirely soluble in the nitric acid, and even in the acids in general, he directs the copper to be precipitated by iron, or by carbonate of soda. In the latter way, one hundred and ninety-four parts of precipitate, according to him, represent an hundred parts of copper. If these ores contain carbonate of lime, he advises their solution to be precipitated by an alkaline carbonate, after the metallic portion has been separated by prussiate of pot-ash. The native sulphate of copper ought to be assayed by means of iron. Lastly, Bergman speaks of a native muriate of copper, of a blue colour verging to green, friable, soluble with effervescence in nitric acid, affording a green solution, and precipitating nitrate of silver in a white coagulum. It is true, that he confounded the green oxide of uranite, with muriate of copper, and we may presume that the specimen in the collection at
Upsal

Upfal was likewise not in reality muriate of copper.

28. The metallurgic operation performed on ores of copper, to extract from them the pure metal, and separate the other metals united with it, is as difficult to describe so as to impart a clear conception of it, as it is to perform. Most men are constantly benefited by the properties of this metal, without suspecting the labour its extraction requires. After the sulphureous copper ore, (which is the most common, and the most difficult to work) is pounded and washed with more or less care; it is roasted at first in the open air, and almost without fuel; because, as soon as the sulphur it contains is once kindled, it continues to burn spontaneously, without requiring to be fed or assisted by other combustible matters. When the fire goes out, from the diminution of the quantity of sulphur, not, as might be supposed, from its being totally destroyed, it is roasted afresh, fuel being added, to impart to it greater heat than was produced spontaneously in its first roasting. This second kind of roasting is repeated twice in succession at least. It is afterwards fused through the coals, and this metal is called *matt*, because it is not yet copper; it has neither its colour, splendor, grain, nor in particular its ductility: its colour is brown, blackish, or deep red; its aspect is as it were vitreous, and its texture very brittle: it is in fact the ore which has yet lost only part of its sulphur. The fusion which

which it is made to undergo, serves to expose fresh surfaces of the metal, and to favour the additional roastings which it still requires. Of these six or seven are again given it in succession, more or fewer, according to the nature of the ore, its hardness, and the quantity of sulphur it contains, and then a new fusion furnishes what is called *black copper*. The matter now begins to be malleable: there still remains in it however, a portion of sulphur, which is only to be separated by the successive operations, to which it is subjected, for extracting the other metals it contains. The copper is alloyed with three times its weight of lead, which is termed *refreshing the copper*: to this mixture the form of flat cakes is given, which are called *cakes of eliquation*. These are immediately placed on two plates of cast iron, placed at the top of a furnace, and inclined to each other so as to leave an open gutter at the lower part. Bars of iron, placed horizontally on these plates, support the cakes of eliquation in their vertical position. The furnace terminating in this apparatus, is called the *furnace of eliquation*: its bottom slopes towards the front. The fire kindled in it gradually heats the cakes of argentiferous copper alloyed with lead: this last mentioned metal, which is superabundant, melts and falls in drops from the groove of the iron plates through the coals, under which it is collected. By virtue of a chemical attraction, it carries with it the silver which it takes from the cop-

per, leaving that metal by itself, and tolerably pure. It is on account of this slow fusion of the lead added to the copper containing silver, that the operation has received the name of *eliquation*. The lead charged with the silver is afterward subjected to cupellation, to extract from it this precious metal, as I shall describe more at large in the history of the latter. As to the copper, which remains in irregular, softened, shapeless, inflated masses, at the top of the furnace of eliquation, after the lead charged with silver, is separated, it is purified or refined by fusion in large crucibles; in which it is kept in a fluid state a sufficient time, to throw off in the form of scum or scoriæ all the foreign matter it contains. From time to time it is tried by dipping into it a rod of iron, which takes up a little copper, and a judgment is formed of the state of refinement, which the metal has attained, by its colour, its grain and its ductility. When these properties announce it to be sufficiently pure, it is run into plates or slabs, or it is fold in those irregular round plates, which are called *rosettes*. This is the reason why the term of rose copper is so frequently employed to denote the metal in a state of purity. To fabricate these rosettes, or obtain the melted copper in this form, the scoriæ that cover the surface of the metal in the crucible are carefully removed; that surface is then suffered to congeal; and when it is become solid, a wet broom is passed over it, and moved about briskly.

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The contact of the cold water occasions the portion of the copper that is fixed, but still soft, to contract, rise in the middle, and withdraw its edges from the crucible, and then it may be separated easily, not only from the sides of the crucible, but from the copper that remains fluid. This raised portion is then removed, rounded, and as it were scolloped on its edges, under the name of *rosette*. Thus the greater part of the copper contained in the crucible is successively taken out in *rosettes*. The portion that remains at the bottom of the vessel is considered as the most pure. Fusion alone, if long continued, serves to purify copper.

29. There are some copper ores, particularly those that are extremely sulphureous, which are treated in another manner, to obtain from them the sulphate of copper, by the efflorescence which they undergo in the air, assisted by sprinkling them with water. In some places, as at Saint-Bel, to separate the sulphur from these ores, they are roasted, and heated in close vessels. Part of the sulphur burned in this operation forms sulphuric acid, which unites with the oxidized copper: what is left of the sulphur burns afterwards slowly, on exposure to the air, and the whole mass of ore is converted into sulphate of copper, which is extracted by washing it with water.

E. Oxidability by the Air.

30. COPPER exposed to cold air, and particularly to damp air, soon loses in it its lustre: it tarnishes, becomes of a dull brown, grows gradually darker, acquires what is called the colour of antique bronze, and at last becomes covered with a sort of green tint, tolerably bright, known to every one by the name of *verdigris* or *verdet gris* as modern (French) chemists will have it. This combustion, which is pretty slow, and even when so far advanced as to carry the copper to the state of green oxide, never penetrates deeply, but stops at the surface, and covers it with a solid coat, which defends the metal from any farther alteration, depends, in this last state, on several complicated effects. The atmospheric oxygen begins by converting the surface of the metal into brown oxide: this oxidation is favoured and accelerated by water. The carbonic acid soon unites itself with the copper thus oxidized: so that the kind of varnish of antique medals, statues, and utensils of various kinds, which antiquaries prize in them, and which they call *patine*, is nothing but a true super-oxygenated carbonate of copper, very analogous to malachite, or mountain-green.

31. This alteration of copper is much more powerful and rapid, if the temperature of the
3 metal

metal be increased. Every one may have observed, how quickly the copper tunnels, used for carrying off the smoke of stoves, change their colour from the moment they are first heated even slightly in contact with the air: they speedily assume a bluish, orange, yellowish, or brown tinge, which at length becomes wholly of a uniform deep brown over all the surface. These different and very beautiful hues are obtained even by cautiously exposing on burning coals, thin plates, or laminæ of copper, as well as that which is in light leaves. By this process leaves of a sort of *foil* are made of various colours, which are chiefly used, after being cut into small pieces, for covering children's toys, to which they are fastened by a kind of mortant or cement, previously applied on them. In fabricating these the succession of blue, yellow, violet, and brown, may be observed: the last colour too is that which remains, and is permanent.

32. When a plate or bar of copper is heated red hot in the air, it burns much more deeply; its outward stratum is oxidized; it loses entirely its lustre, becomes of a deep brown colour, and this stratum, which is oxidized brown, no longer adheres to the metal. Accordingly, on letting it cool, its surface, though smooth and polished before, appears not only dull and dusky, but also unequal, rough, wrinkled, brittle, and liable to break off on being struck. Thus by striking

ing a piece of copper, kept red hot for some-time, crusts of brown oxide are saturated from it, known by the name of *scales* or *beatings of copper*, under which the metal re-appears of a fine rose-colour. This species of oxide is easily obtained pure, by dipping into cold water a great number of times following a piece of copper heated very red. At each of these operations the cold water condenses and suddenly contracts the pellicle of oxide formed on its surface; which, urged by this sudden contraction, breaks, separates in little fragments, and falls to the bottom of the water in coarse powder. On drying this powder, and levigating it, we have a brown powder almost impalpable. The copper in this combustion, which has been supposed its first degree of oxidation, but which can never be carried farther, as will appear presently, is increased by twenty five parts, and absorbs this proportion of oxygen to one hundred of the metal. This brown or black oxide is easily reducible to the metallic state by the action of the carbon and hydrogen of oils, assisted by heat. Accordingly founders of copper content themselves with throwing the beatings into the crucible where they have metal in fusion, and particularly brass, the zinc contained in which, seizing the oxygen of the brown oxide, restores it almost immediately to the metallic state.

33. The brown oxide of copper, which varies from a deep red, or chestnut colour, to a dark brown,

brown, acquires this colour only by a sort of fusion or vitrification. When it is heated so as to become slightly red hot in contact with the air, and affixing it so as to increase the surface exposed to the atmosphere, it becomes much deeper, and almost black. It has been thought, that under this black tint it was of an intensely deep blue; this shade was considered as a second degree of oxidation of copper, in which the metal appeared to contain sixteen or twenty parts of oxygen, while only eight or ten were admitted in the brown oxide: but it is now known, from the late researches of Mr. Proust, that these two colours belong to the same oxide in two states, or in two modifications of form; that both are equally oxides with twenty-five parts of oxygen to the hundred; that the oxidation of copper cannot be carried farther; and that it never attains a higher degree, since the green colour, which was deemed a *maximum* of oxidation, is owing only to the union of an acid, and contains no more oxygen than the proportion just mentioned, or twenty-five per cent.

34. Though the brown or black oxide of copper is sufficiently easy to be reduced to the metallic state, it enters notwithstanding (the brown in particular) into several vitrified combinations, and tinges the glass of a chestnut brown, or deep red. A brown oxide of copper may be fabricated very readily by heating two or three parts of copper filings with one of
green

green oxide; the acid and water contained in which convert the whole mass of copper into an oxide with great promptitude. It must be noticed too, that the blood-red colour, or brilliant brown, of oxide of copper, which the first black oxide, or brownish oxide, often assumes, when it is urged with a brisk fire, is but the sign of a sort of fusion, of a kind of vitrification, and not of a less oxygenation, as has been supposed. It is thus that the copper, in the furnaces in which it is refined, is covered with a red vitreous coat, which is found also on the rods, with which specimens are from time to time taken out.

35. All the facts which I have just related respecting the oxidation of copper, belong only to its slow or slight combustion: there are others pertaining to the history of its rapid and powerful combustion, with which likewise it is of essential import to be well acquainted. When the action of fire on copper is strongly urged, when it is thrown, for instance, in the form of fine filings, into a very strong fire, or when it is heated in a crucible to a white heat after having been melted, it burns much more rapidly than in the former cases; it experiences a real conflagration; it even yields a very brilliant green flame. Accordingly it is employed in the composition of the coloured fires of the smaller kinds of fireworks, particularly those which are called table fireworks. The same effect which is perceptible at the surface of the crucible,

app.
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crucible, in which copper thoroughly fused and very red, if melted and stirred, is produced by sending through this metal in a small piece, or in wire, or in thin leaves, an electric discharge. It instantly emits a greenish flame, breaks with decrepitation, and is dispersed in smoke or dust in the air. It may be collected on paper, which you will find covered with a reddish-brown oxide. It is to this property likewise we are indebted for the green colour which we so frequently see in the flame of various combustible substances, but particularly alcohol, when cupreous salts have been mixed or dissolved in it. Notwithstanding the activity of this sort of combustion, and its difference from the slow oxidation I before described, the oxide resulting from it uniformly contains but twenty-five parts of oxygen to an hundred of metal, and completely resembles that which is obtained by the former kind of combustion: it is fully proved, that there is but one species of oxide of copper.

F. Union with Combustible Substances.

36. WE are yet ignorant of the union of copper with the first combustible substances, particularly with azote, hydrogen, and carbon, with which it is even believed to be incapable of combining. All we know is, that hydrogen and carbon decompose the oxide of this metal, take from it its oxygen, and revive it in a metallic state, at a red heat. It must be observed, how-

ever, that hidrogen gas reduces the oxide, and even some of the salts of copper, as well as those of several other metals, by simple contact, when they are exposed to it diluted in water, or in a state of solution, and that it does not produce the same change in them, when they are exposed to its action in a dry form. I shall resume this reduction of moist metallic salts and oxides by hidrogen gas in the histories of gold, and silver, the oxides of which are much more capable of it than those of copper, where I shall notice the experiments and theory of Mrs. Fulhame, an English lady, who has paid great attention to this subject.

37. Phosphorus easily combines with copper and makes with it one of the best known metallic phosphurets, as it is the most commonly obtained, in consequence of the practice of evaporating phosphoric acid in vessels of this metal. Pelletier has described with great care the properties of phosphoret of copper, after having observed, that the residuum of the distillation of phosphorus, made with phosphoric acid, evaporated in copper vessels, which are in other respects very convenient for this operation, contained a combination of phosphorus with copper, in the form of little distinct grains, or of pieces somewhat larger. Pelletier prepared this phosphoret by heating in a crucible equal parts of copper shreds and glacial phosphoric acid, with one sixteenth of the weight of the whole of powdered charcoal. Margraff had before obtained

obtained a phosphoret of copper, by distilling an oxide of this metal with phosphorus. The French chemists likewise discovered, that this compound might be prepared, though less completely, by the fusion of equal parts of copper in shreds and glacial phosphoric acid; and particularly by throwing phosphorus on copper heated red hot in a crucible. In the last case, the copper melts as soon as the phosphorus comes into contact with it, and it absorbs nearly fifteen or twenty per cent. of the phosphorus. The saturated phosphoret of copper is of a shining and metallic whitish grey, often tinged with the prismatic colours, granular, compact, and hard in its texture. It is much more fusible than copper; yet it does not melt in the flame of a candle, as Margaff asserted. Exposed to the fire under a muffle, or treated with the blow-pipe, it melts; the phosphorus rises to the surface, and burns with brightness and deflagration; and the copper remains in a sort of blackish scoria. In the air it cracks, changes colour, loses its lustre, grows black, and is converted by a kind of efflorescence into phosphate of copper: in close vessels, however, it may be kept for whole years without alteration. In the fabrication of this phosphoret with the glacial phosphoric acid, there is always a small portion of vitreous scoria, black, and more or less thoroughly melted, which covers or envelopes the button collected at the bottom of the crucible.

38. There are several methods of obtaining the combination of sulphur and copper, and, according to the circumstances attending the operation, different compounds are produced. If sulphur in powder be mixed with copper filings, and made into a paste with water, this paste, on exposure to the air, swells a little, cracks, increases in bulk, heats slightly, and forms at length a brown mass, which effloresces slowly in the air, and is converted in it into sulphate of copper. But this action is infinitely less marked than that of iron treated in the same manner. If equal parts of sulphur and copper in powder be heated in a crucible, we obtain by fusion a mass of a deep colour, a kind of short, brittle *matt*, more fusible than the metal itself. For dyeing and printing cloths this compound is prepared by stratifying plates of copper with sulphur in a crucible. When the whole is melted, the matter is powdered, and used under the name, now old, of *æs vene-
ris*. This is the same substance as the preceding. In some manufactories this process is employed for preparing sulphate of copper, by heating the compound strongly in a furnace.

The Society of Chemists at Amsterdam has made some new observations on the sulphuret of copper. By gently heating fine filings of copper along with sulphur in a glass tube stopped at one end, which is placed in a furnace amid the coals, the mixture melts into a very fusible brown mass, which crystallizes in very long
prisms

prisms or radii of a deep red. If it be kept melted, or merely in a soft state, for some time, it grows red, and seems to be penetrated with fire without its coming from the vessel itself, but by the re-action of its own constituent parts: it emits, as if by taking fire, a light of the most beautiful red colour, and of the most vivid brightness; so that the Dutch chemists, who imagined they saw in this phenomenon a real combustion without the contact of air having any concern in it, drew some inferences from it repugnant to the pneumatic system. But it is more easy and more natural to ascribe this effect to the phosphorescence of the compound, or indeed to a little air contained in the apparatus, since it is certain, that the experiment was not made with all the precautions necessary to insure its total absence, and to reject every idea of combustion without oxygen. For, if we were to suppose, on the first appearance, that this artificial compound of sulphur and copper actually took fire without air, might we not conceive, that a small quantity of water had here supplied this principle? Besides, can a single fact, some circumstance of which undoubtedly may have escaped the able chemists of Amsterdam, be capable of inducing us to believe, that combustion can take place without air, and without oxygen? On seeing this phenomenon with my own eyes, I have considered it as a mere phosphorescence, as a change and sudden augmentation (*qu.* diminution) of capacity for caloric,

loric, and as a simple expulsion of light, or conversion of caloric into light: which appears so much the more evident, as after it has taken place, the compound is still sulphuret of copper, though it ought to have been changed to the state of a sulphate, if it had undergone a real combustion; and as it retains its combustible property without diminution. The fact, however, deserves to be considered with more care than it has hitherto been.

39. Copper easily unites with almost all metallic substances by fusion, and almost all the compounds it forms, possess properties of more or less value, on account of which, most of them are employed in the arts. There is no metal which so readily assumes different forms in its metallic combinations; and this is one of the principal reasons that induced the alchemists to give it the name of *Venus*. United to arsenic by fusion in a crucible well closed, and with muriate of soda to cover the melted matter, it forms a white, short, brittle metal, which some authors call *white tombac*. Zinc or tin is frequently added to this composition, which serves for making various utensils and trinkets. Wallerius advises, to combine equal parts of arsenic and copper with a sixteenth of silver. In fact he took white arsenic, or arsenious acid. Most authors employ black flux and powdered glass, to assist the fusion and combination. Becher has given a very long and minute formula, by which he assures us, we may obtain from the combination

combination of copper with arsenic, a white, ductile metal, resembling silver. Swedenborg has collected a number of different processes, for making this composition. Citizen Baumé has treated it in divers ways: he has frequently had it brittle, and remarked that fire rendered it ductile, without destroying its white colour. He prepared it either with arsenious acid and fixed alkali, or with the acidulous arseniate of pot-ash or *neutral arsenious salt* of Macquer, or lastly by substituting brass for common copper. In the arts, many metallic mixtures are made with copper and arsenic, by adding to them different metallic substances in great variety of proportions.

40. The combinations of copper with tungsten, molybdena, chrome, titanium, uranium, and manganese, have not yet been described, or even their properties noticed; though we know, that most of these metals are capable of uniting with it, and rendering it brittle, and more or less pale. Many researches remain to be made respecting these new mixtures, which, on a careful examination may certainly furnish products very useful to the arts, in consequence of differing in their properties from the mixtures already known. Besides, the facility with which copper is known to unite with other metallic substances, ought to induce chemists to try these compositions, which will furnish them with the means of reducing and fusing those of the new metals, the infusibility and intractability of which,

which, have prevented us from yet attaining a knowledge of their characteristic properties.

41. The combination of copper with cobalt is somewhat different, and little known. Those authors, who have said a few words on the subject, particularly Wafferberg in his Institutes of Chemistry, affirm, that this mixture is similar to cobalt itself, both in texture and fragility. According to Cronstedt, copper forms with nickel a white, hard compound, not ductile, and easily destructible by the air. This author has remarked, that, notwithstanding the various proportions in which he made this mixture, the copper constantly betrayed itself by the green or brown colour it imparted to the glass of borax. We do not know what pure nickel forms with copper; for that which Cronstedt employed, as I have elsewhere said was mixed with arsenic, cobalt, and iron.

42. Bismuth fused with copper in equal parts forms a brittle mixture, of a pale red. In the compound made with nearly an eighth of bismuth, Gellert found considerable brittleness, a whitish red colour, and a texture with facets indicating almost cubical fragments in its grain. Its specific gravity was precisely the mean of the two metals. Muschenbroeck, who has described a series of different mixtures of copper and bismuth, and ascertained their various degrees of tenacity, observed this property to diminish in proportion to the abundance of the bismuth. The manufacturers of small
works

works in brass or tombac, among others of bodkins and spoons, put a little bismuth into their composition, without knowing the end this addition answers: it is an ancient practice, which they follow simply on this account.

43. Antimony unites with copper very easily by fusion. When they are mixed in equal parts, the product is a metal of an agreeable violet colour, the only one of the kind among metals. Gellert found this mixture specifically heavier than the mean of its component parts. This singular composition has a lamellated and fibrous texture: it was the *regulus of Venus*, formerly fabricated by apothecaries for the preparation of the too-famous *lilium* of Paracelsus. A mixture was likewise made according to a prescription for alchemical purposes, composed of equal parts of *martial regulus* and *regulus of Venus*, which, they say, formed meshes and reticular cavities on its surface. This was called *Vulcan's net*, because *Mars* and *Venus* seemed to be enclosed in it.

44. The union of mercury with copper, and the formation of an amalgam with this metal, occupied much attention in the laboratory. In the order of adhesion, which the metals, soluble by mercury, are capable of contracting with it, and which answers to their solubility, copper holds only the eighth rank, according to the experiments of Citizen Guyton, and has below it only antimony, iron, and cobalt. This shows, that it is not capable of uniting with it easily;

easily; accordingly, we cannot accomplish the amalgamation, unless it be triturated with the mercury in a state of great division. Among the chemists who have spoken of this combination, some direct thin leaves of copper triturated with the mercury, after they have been previously rubbed with vinegar, or with common salt. Others direct the trituration of copper filings with the nitric solution of mercury, the oxide of which is reduced by the former metal, and precipitated from its solution; adding to it a little fluid mercury, and washing it copiously with water. There are some, who advise us to take the copper dissolved in nitric acid, to precipitate it in a metallic state by means of iron, and to triturate it quickly with running mercury. There are also other processes, which require combinations with vegetable acids, and of which I shall speak hereafter. In whatever manner this combination is made, it is reddish, sufficiently soft to receive the most delicate impressions when a little heated, and capable of growing very hard in the air. Heat easily decomposes it, and separates the mercury.

45. The combination of copper with zinc is one of the most important mixtures that exist; or rather, according to the different proportions of the metals, it gives rise to different compositions of great utility in the arts. Muschenbroeck has carefully described some properties of several of these compositions. Equal parts
of

of copper and zinc yielded him a metal of a fine golden yellow, a parallelopiped of which, one-tenth of an inch in diameter required 108 pounds to break it. Its specific gravity was 8,047. Two parts of copper and one of zinc formed a metal of a pale gold colour: one part of copper, and three quarters of a part of zinc, a fine gold coloured metal, very soft under the file: one part of copper, and one fourth of zinc, a composition of a finer colour than that of brass. Gellert has indicated the specific gravities of these mixtures as greater than the mean. Wallerius informs us, that a mixture of five parts of copper with three parts of zinc is still a little ductile. Citizen Borda has found, that the density of brass was about one-tenth greater than that of the two metals taken separately.

46. To these general observations on the mixture of copper with zinc, it is proper to add an account of the principal differences between the metals most commonly produced by it. According to the proportions in which they are combined, we have latten or brass, prince's metal, pinchbeck, tombac, and similor. Latten and brass are fabricated either by stratifying sheets of copper, or fusing this metal, with a mixture of calamine, or native carbonate of zinc, and charcoal. Into compositions of this kind, zinc enters in the proportion of a fourth or fifth of the weight of the copper; and then this metal is sufficiently ductile, to answer a

great many purposes. Macquer has remarked, that zinc would unite with three parts, and even with two, of copper, depriving it of scarcely any of its ductility when cold: it is this that renders brass so useful and valuable. By this mixture the quantity of the metal is increased a fourth, or even a third; a pleasing colour, resembling that of pale gold, is given to it; and it is rendered less subject to oxidation, and to produce verdigris. Indeed it is somewhat less ductile when heated, than while cold, on account of the much greater fusibility of the zinc than of the copper. On keeping brass in fusion over a strong fire, the zinc separates, is volatilized, burns with flame, and the mixture, being decomposed, returns to the state of pure red copper. Though the terms *latten* and *brass* are nearly synonymous in chemical writers, the term *laiton* (in French) is most frequently used for brass drawn into wire: this is sometimes whitened only on the surface by the zinc, with which it is coated as it were. [Our English term *latten*, now obsolete, was used chiefly for brass in sheets, or in a thin form.]

The metal of prince Rupert was a mixture analogous to the preceding, in which the proportion of zinc is less than in brass and the deeper colour of which more nearly resembles gold. Every workman has his particular processes for making this metal, which is used only for some ornamental trinkets. It is the same with pinchbeck, tombac, and similar, three
other

other mixtures of copper with zinc, which differ little from each other, and are only varieties of brass, differing a little in colour. To obtain them fine, it is of importance to have the two metals very pure, and to vary their proportions in a greater or less number of trials, and according to the colour desired. In ancient works on chemistry, there are receipts more or less complex for preparing these metals, with a view to imitate gold. Instead of taking pure zinc and copper, many direct calamine and verdigris, which they mix with several salts, and expose a longer or shorter time to a less or greater degree of heat. A great number of these formulæ may be found in Swedenborg's dissertations on copper and brass, *aurichalcum*; and in the works of Lewis, Justi, Cramer, Wallerius, Gellert, Tassari, Rinnman, and Klinghammer.

To what I have said I shall only add an abstract of what Citizen Vauquelin has lately done, with respect to the analysis or assay of this important composition. To find the proportions of the two metals composing brass, this chemist employed with advantage the method of solution by nitric acid. When it was complete, and nothing more remained to be dissolved, he precipitated the two metals by pot-ash, which he added in sufficient quantity to dissolve altogether the oxide of zinc; and as the oxide of copper is not soluble in it, this remained in a blackish powder, which was se-

parated, washed, and weighed. A fifth of the weight of this precipitate, being subtracted for the oxygen united to it, the remainder gave the weight of the copper; and what this fell short of the metal analyzed, was the weight of the zinc. This experiment was verified by precipitating a second nitric solution with zinc, which separated the copper in the metallic state, and afforded the same quantity of the latter metal, as was indicated by the former trial.

47. Copper easily unites with tin. This kind of mixture is extremely useful in the arts. With it are made bronze, the metal of statues, what are called brass cannons, bell-metal, metallic mirrors, and the tinning of copper vessels. Its properties therefore should be carefully studied. In general, tin greatly diminishes the ductility of copper, and augments its tenacity, hardness, and sonorous quality. Muschenbroeck has proved by his experiments, that copper acquired the greatest firmness of which it is susceptible when one part of tin is added to five or six of this metal: and that the more the proportion of tin was increased, the harder and more fragile the composition became; so that at length the file would not touch it: and in this state it was fit only for fabricating mirrors. Hence this experimental philosopher concluded, that for gun-metal, one part of tin only should be used to five or six of copper. The density and specific gravity of this compound, are greater than the mean in the proportion of 8,265 to 7,638.

Wallerius

Wallerius has given still more precise details respecting bronze, than Muschenbroeck. According to him, for making gun-metal, twelve parts of tin should be combined with a hundred parts of copper; to which a little brass may be added with advantage. By mixing a hundred parts of copper with twenty parts of tin, we have a loudly-sonorous mixture, of a yellowish grey, fit for casting bells. Swedenborg advises us to make gun-metal, by fusing together an hundred parts of copper and twelve or fifteen pounds of old tin, and by frequently mixing with these metals in fusion, pieces of implements of bronze. Savary proposes only ten or twelve parts of tin to an hundred of copper for gun-metal, and twenty or twenty-four to an hundred for bells. He adds, that two parts of antimony are added to the latter, to render the found more agreeable. In the composition intended for fabricating cannons, which ought to possess sufficient solidity not to burst with a double charge of powder, and at the same time not to be so soft as to have the shape altered by the force of the recoil, it is of importance to observe, that the mixture of the two metals is not homogeneous and equal in all its parts, unless the matter in fusion be well stirred and agitated. Without this, an imperfect mixture takes place; so that the tin, or copper most loaded with tin, occupies the upper part, and the bottom is nearly pure copper; and the whole mass forms as it were, separate strata of several different mixtures,

mixtures, from that at the top of the crucible, which contains most tin, to that at the bottom, which contains least. I have already made the same remark on other compositions, but it is still more important in the history of bronze, on account of its great utility, and the various purposes for which it is designed. It may be remarked here, that the bronze of statues differs from that of cannon only by containing a more or less considerable proportion of tin, according to the colour that it is wished to have.

48. Bell-metal differs from bronze chiefly in the proportion of tin, which is greater, and in being more brittle. The most usual proportion for this composition is twenty-five of tin to seventy-five of copper. On analyzing pieces of bells by acids, we frequently find either their proportion a little different from this, or some other metal in them, as zinc, antimony, bismuth: sometimes we even discover in them silver: but these metals are not essential to them, and almost always come from brass, and *potains*, a sort of bad compound of copper, tin, lead, &c.; or some pieces of old plate, which credulity and superstition formerly threw into the furnaces where bell-metal was melting. In the fabrication of bell-metal, we particularly observe the singular property tin possesses, of diminishing the fine colour of copper, and even causing it to disappear. The mixture for bells is of a white grey, of a close and hard grain,

very difficult to file, and of a specific gravity greater than the mean of the two metals combined ought to give. All these characteristics indicate, that the copper is intimately penetrated by the tin, and all its pores in a manner filled with the molecules of the latter. This metal is more fusible than copper. To assay it, it is treated in powder with nitric acid, which dissolves the oxidized copper, and leaves the tin as a white insoluble oxide: It was formerly supposed, that these two metals could not be separated, and that it was impossible to extract the copper; so that it was imagined the copper was lost, and that there was no other way of turning it to account, but to add copper to it in such proportion as to render it fit for gun-metal, or to make those white, hard, and brittle mixtures, of which bells for clocks, buttons, trinkets, &c. are formed. But this prejudice, propagated by men whose interest it was that bells should not change their form, did not long stand against the first look which the French chemists threw on this mixed metal, when the wants of their country called their attention to the subject. Many modes of extracting copper from bell-metal were found: slow fusion merely, with the throwing of a little water on the surface of the melted metal, was sufficient for the purpose in refiners workshops, in full activity. By this process, the tin is oxidized, and floats on the surface of the bath in the form of scoriæ, which carry with them a little copper it is true, but which
when

when separated from the refined copper they cover, are reduced and re-melted apart, to make a white brittle metal, useful for various purposes. In several national and other French workshops, the copper of bell-metal is still extracted in the great by a process which I proposed in 1790. This consists in oxidizing part of the bell-metal into pulverulent scoria, and stirring them among six parts of the same metal fused in a reverberatory furnace. The tin, having much greater affinity for oxygen than the copper has, the portion of the former metal contained in the mixture in fusion, absorbs this principle from the oxidized copper of the scoriæ last added; so that the copper separates from the tin, which is thus burned and scorified, and at the same time is augmented by the copper contained in the scoria added, which yields its oxygen to the tin. To accomplish the same object, and to oxide the tin of the bell-metal, Pelletier recommends the addition of manganese to the metal in fusion. Some other chemists have successfully employed muriate of soda, projected on the melted bell-metal, by means of which, they have separated the tin. This parting of bell-metal is a new art, which was created, and speedily carried to perfection by the French republic, to the astonishing military successes of which it contributed.

49. A mixture of three parts of tin and one of copper, fused with a little arsenious acid and black flux, which reduces the latter, yields a stiff,

stiff, hard compound, of a steel colour, susceptible of a bright polish, little alterable, which is used for fabricating reflecting mirrors for telescopes, optical experiments, &c. We find besides, in Kunckel, Cardan, Becher, and Swedenborg, many different compositions for making this speculum metal. Becher directs for it eight parts of copper, one of tin, and five of bismuth : Cardan, three parts of copper, one of tin and silver, and an eighth of antimony : Kunckel, three parts of good tin, and one of copper, which he fused with a little tartar, alum, saltpetre, and arsenious acid. Tin is only hardened and rendered brighter, when it is alloyed with $\frac{1}{11}$ of copper. Antimony is frequently added to these two metals with the same intention.

50. The tinning of copper is nothing but an extremely thin or superficial mixture of copper with tin. It is employed to hinder the copper from rusting ; and to prevent food prepared in vessels of this metal from dissolving a portion of it, and acquiring a poisonous acrimony. That the tinning may be performed with good success, it is necessary, that the surface of the copper vessel to be tinned is very clean, and perfectly metallic. Accordingly the workman begins with scraping this surface with the blade of an iron tool made for the purpose, rubbing it all over sufficiently hard, till it is every where clean and shining. It is then rubbed with muriate of ammonia, and set over burning coals. When

When it is sufficiently heated, powdered resin is thrown into the vessel, which, by covering the metallic surface, prevents it from oxidizing. Lastly, melted tin is poured in, or the vessel is rubbed with a piece of tin, which is immediately melted by the heat, and which is applied over all the surface of copper by means of a wad. Instantly the copper, which was of a fine red, becomes of a shining silvery white, from the uniform application of the tin over every part. There is but a very slight layer of tin, which thus forms one substance with the copper. It would be in vain to apply fresh layers and new thicknesses of it, for they would not acquire the same adhesion, the same hardness, the same infusibility, as that which covered the copper. In a heat capable of melting tin, these new layers would run, and collect in globules, or clots at the bottom of a tinned vessel; because the second tin, which was added to the first, would remain as tin, and retain all the properties of tin; while the first, actually adhering to the surface of the copper, and forming a compound with it, is thus rendered infusible at the temperature that melts tin. We have reason to be astonished at the small quantity of tin which thus combines with and attaches itself to the copper in tinning; and we might naturally apprehend dangerous effects from the copper, which is separated from our food only by a leaf of tin of almost incalculable thinness, had not long experience taught

us that this slender leaf is sufficient to prevent the copper beneath it from coming into contact with the contents of the vessel. Bayen, in his inquiries concerning tin, has found, that a stew-pan, nine inches in diameter, and three inches three lines deep, acquired the addition of twenty-one grains only by tinning. We must be attentive, however, not to let food, particularly if it contain any thing acid, remain in tinned copper vessels; and frequently to have them tinned anew, to avoid all apprehension of danger. It is of importance, likewise, to use nothing but very pure tin for this purpose: for that which contains lead, and particularly pewterers' solder, which contains half its weight of it, exposes us to all the disorders to which lead may give rise. It has been proposed to make infusible and thick coatings of tin rendered infusible by means of iron, silver, or platina. Lafolie, a chemist of Rouen, has even endeavoured to substitute in the stead of tinned copper vessels, to keep up the prejudices against the use of which is certainly prudent, stew-pans of wrought iron covered with zinc; and it is much to be wished that the use of these should be more common.

51. Copper mixes very well with lead by fusion. When the lead exceeds the copper, the mixture has the grey colour of the former, and is tolerably ductile; though it is brittle when hot, on account of the great difference of fusibility between lead and copper. To this difference

ence is owing the utility of lead in the metallurgic process which I have described above under the name of *eliquation*. This mixture of lead and copper is employed in some of the arts, particularly in the fabrication of certain sorts of printers' types for the large letters. Savary says, that the proportion requisite for this purpose is an hundred parts of lead to twenty or twenty-five of copper.

52. Copper is capable of uniting with iron likewise, but much more difficultly than with most of the preceding metals. The more iron is combined with copper, the more does the compound approach to a grey colour; lose its ductility, and become difficult to melt. On fusing these two metals in a crucible, we always find unmixed iron remaining over the copper, to which it strongly adheres. This fact explains how the two metals solder together intimately, and pretty easily. Grains or filings of iron are frequently found disseminated in bubbles in the copper, when the two metals have not been heated sufficiently to promote their mixture. Almost all chemists agree respecting the difficulty of uniting them.

G. Action on Water, and on Oxides.

53. What I have already shown concerning the properties of copper, sufficiently proves that this metal has too little attraction for oxygen, to be capable of depriving water of this principle:

ple : accordingly modern chemists suppose, that copper does not decompose this oxide of hydrogen ; as they see besides, that hydrogen decomposes the oxygen of copper, even coloured green ; the instantaneous contact of this gaseous substance being in fact sufficient, to bring the oxide back to a brown colour. There is one circumstance, however, in which it might seem, that this decomposition of water by copper, really takes place: it is that in which this fluid, which touches and bathes the metal without action as long as it is hot or in vapour, cools and condenses on its surface. In this case we constantly see the places occupied by drops of the condensed and cooled liquor become covered with green oxide in the space of a few hours ; and this phenomenon recurs too frequently in common life, for chemists not to have been struck with it. At the highest temperature, when copper is melted and red hot, water falling on it excites a commotion, is suddenly converted into vapour, and pushes before it jets of liquid copper, which are very dangerous in casting this metal, as all copper-founders know, who take the greatest care to dry their moulds: but even in this phenomenon, we can neither say nor imagine, that the water is decomposed, any more than in the contact of the vapour of water condensed by refrigeration. The first deflagration appears to be owing to the violent and sudden vaporization of the water. The oxidation of the copper in the second case is

is produced by the union of several attractions particularly by that of the oxygen and the carbonic acid of the atmosphere for copper and its oxide. This is the reason why the oxidation which takes place so readily in open vessels, does not occur in close vessels.

It is by the same combination of several attractions, particularly assisted by that which have called *disposing attraction*, that copper decomposes water when it is combined with sulphur: it is to these co-operating powers, that the spontaneous sulphatization is owing, which native sulphurets of copper undergo in the air after being wetted. There is every reason to believe, that the same thing happens to the phosphuret of this metal, when it grows black in the air, according to the observation of Peltier, as well as to several mixtures of this metal, when they happen to be placed in similar circumstances. We shall see presently, that the same theory naturally presents itself in the action of copper on certain acids, or during its solution in some of these burned substances.

55. It is easy to conceive, from what has hitherto been said, that copper should have but little action in the greater number of metallic oxides: in fact there are very few from which it is capable of taking their oxygen; on the contrary, its own oxides are easily decomposed by most other metals. Manganese, zinc, tin, and especially iron, have this property in an eminent degree. Mercury is of all metals that
which

which yields its oxygen most readily to copper : so far that the latter precipitates in a metallic state almost all the solutions of quick-silver ; and that the putting of plates or pieces of copper into fluid mercurial salts, is sufficient to whiten them by the precipitation of the mercury in a metallic state, and to give a blue colour to the solutions which before were perfectly colourless. Sometimes this process is employed even to form on the surface of copper, a kind of silvering, which it must be owned, however, is of little solidity or duration. Copper precipitates likewise, at least in part, the super-oxygenated sulphate of iron ; not that it takes the oxygen from the tin, but because the highly-oxidized oxide of this metal has so little adhesion to the sulphuric acid, that it instantly yields its place to the copper.

H. *Action upon the Acids.*

36. It has always been said, that no metal is more alterable or soluble by acids than copper : and in fact there is no acid, even among the weakest, which is not capable of colouring this metal, if put into it and covered with it, either blue or green ; and which, consequently, is not capable of oxidizing it by the help of water, and of afterwards uniting with its oxide.

Sulphuric acid does not attack copper unless it is concentrated, and at a boiling heat : copper then decomposes this acid, takes from it
part

part of its oxygen, and disengages from it much sulphureous acid gas. For this process it is usual to take two parts of acid, and one of the metal. Kunckel directs distillation to be employed. This combination is most frequently made in a matrafs: the process is continued, till a dry mass is obtained, which is of a dirty or brownish grey, according to the proportion of the two substances, and the heat given to it. This residuum is afterward washed with distilled water, which assumes a fine blue colour. A little brown oxide frequently remains, which does not dissolve. The blue liquor, evaporated to a pellicle, and cooled slowly, yields rhomboidal crystals of the same colour. These are obtained almost to the end of the evaporation of the liquor. The sulphuric acid, even when weak, easily dissolves the oxides of copper, and forms with them the same sulphate of copper as that of which we have spoken.

57. Sulphate of copper is prepared in the great, either by the evaporation of certain waters, which hold it in solution, or by burning native sulphurets of copper, or by leaving these sulphurets to effloresce or sulphatize in the air, after having wetted them. When the sulphatization is effected, the matter is lixiviated with water, and the lixivium, after evaporation, is left to crystallize in large vessels, in which it deposits considerable masses of blue crystals. This salt was formerly termed *blue vitriol*, *Cyprus vitriol*, *vitriol of copper*, *blue coppers*,

and *vitriol of Venus*. It has an acrid, metallic, styptic, and almost caustic taste. Though it has always been described as crystallized in rhomboids, this vague expression is insufficient in the present day. The following is the manner in which Citizen Haüy describes the crystallization of sulphate of copper. Its primitive form is an oblique angled parallelepiped, which may be considered as an oblique prism, of which the sides are inclined to each other in angles of $124^{\circ} 1'$, and $55^{\circ} 59'$, and the base makes with one of the sides an angle of $109^{\circ} 21'$, with the opposite side one of $70^{\circ} 39'$. The feldt-spar is the only salt besides this which has an oblique-angled parallelepiped for its primitive form; but the faces composing the same solid angle in that stone have different angles. The prism of sulphate of copper passes, by decrements simple in their description, to the octahedron, and the decahedron: round each base, likewise, are formed marginal or angular facets, solitary, binary, or ternary, which constitute a series of varieties, all determined with precision by the help of the theory which Citizen Haüy has discovered.

58. Sulphate of copper melts quickly over the fire, by the help of its water of crystallization; soon loses thirty-six per cent. of its weight, and dries into a powder of a blueish white. If the fire be then augmented, it gives out its acid. It has been remarked, that it is more difficult to decompose than the sulphate of

iron. The residuum of this decomposition by fire is a blackish oxide, always containing twenty-five parts of oxygen to a hundred parts of metal. Mr. Proust, to whom we are indebted for this last remark, gives the following proportions for the component parts of sulphate of copper: black oxide of copper, thirty-two; sulphuric acid, thirty-three; water, thirty-five. It alters a little in the air, losing its water of crystallization, and efflorescing in the form of a whitish blue powder; but this efflorescence is confined to the surface of the salt. It requires but four or five parts of water, at the temperature of ten degrees, to dissolve it: boiling water dissolves half its weight: accordingly it crystallizes almost as well by refrigeration as by slow evaporation. Phosphorus, and phosphorated or sulphurated hydrogen gas, separate from it the copper, which they more or less completely reduce. No acid acts on the sulphate of copper.

59. The earths and alkalis decompose it, and precipitate its solution into a blueish grey oxide, which becomes green when dried in the open air, by absorbing the carbonic acid of the atmosphere.

If but a small quantity of liquid caustic potash be poured into the solution of sulphate of copper, the greenish precipitate obtained, which forms in a solution of cupreous sulphate, as this salt is not in this case wholly decomposed, is a particular species of sulphate of copper, in which, according to Mr. Proust, the
acid

acid is at the *minimum*; in other words, it is oxide of copper, with a little sulphuric acid. This salt, the same chemist observes, loses fourteen per cent. of water by distillation: when treated with pure pot-ash it is reduced to sixty-eight of black oxide. It contains therefore sixty-eight parts of black oxide, eighteen of sulphuric acid, and fourteen of water. It appears, that sulphate of copper with the *minimum* of acid may be obtained by the decomposition of sulphate at the *maximum*, by heat.

60. If, instead of partly decomposing the sulphate of copper by pot-ash, we employ this alkali in excess, all the acid of the salt is taken up by it, and a blue oxide is thrown down, which Mr. Proust considers as a peculiar compound of black oxide, the only oxide of copper he admits, together with water. He calls it *hydrate of copper*. When I come to the nitrate of this metal I shall speak of it more at large. Ammonia, by decomposing the sulphate of copper, and at first precipitating its solution, soon dissolves the precipitated oxide, when an excess of this alkali is added, and assumes a very rich and brilliant blue colour.

Sulphate of copper unites in triple salts with several alkaline, earthy, and metallic sulphates. With heat it decomposes the nitrates and muriates, being at the same time itself decomposed, and expelling the nitric and muriatic acids. It acts on many metallic salts, which it decomposes by double elective attraction. The alkaline

phosphates and borates likewise precipitate it by double attraction. The carbonates, by precipitating it, produce carbonate of copper, which becomes of a fine green in the open air. Many metals, particularly zinc, tin, and iron, decompose it, and precipitate from it, the last especially, metallic copper, by attracting the oxygen from its oxide. The solutions of manganese and tin turn it brown, and throw down the copper in brown oxide. From this property of iron it is employed, as I have said above, to separate the copper from the native solution of this salt, which produces the copper of cementation.

61. The sulphureous acid, according to the experiments made on the metallic sulphites by Citizen Vauquelin and myself, does not attack copper. This metal, left a long time in contact with and covered by sulphureous acid, has neither its lustre nor its weight diminished. We have also seen this metal give out only sulphureous acid gas with sulphuric acid; and for this reason there is no such thing as sulphurated sulphite of copper. But the oxide of this metal unites speedily and quickly with sulphureous acid. This saline composition is made at once by pouring a solution of sulphite of soda into a solution of sulphate of copper: at the instant of mixing these two liquors, a lemon-coloured precipitate is formed, and afterward small crystals of a greenish white are deposited, which grow deeper coloured on exposure to the air; after

after these are deposited, the liquor yields on evaporation sulphate of soda. All the experiments made on the yellow precipitate, and on the greenish-white salt, prove these substances to be equally sulphite of copper, and that the first contains most copper, which is the occasion of its yellow colour and insolubility. Thus there is an unequal distribution of the oxygen between the two portions of the copper, and two sulphites a little different are formed: Each of them, when heated with the blow-pipe, melts, grows black, acquires a grey colour similar to that of *fahlertz*, and is reduced to the metallic state with ebullition. Heated in a glass tube, the greenish crystallized sulphite becomes at first yellow, and afterward of a chestnut red: sulphureous acid is at first extricated, and afterward sulphuric acid: part of the salt remains in a grey sulphuret, and another portion, fusing with the glass, gives it a brilliant red colour. We here see the oxide of copper yield its oxygen to sulphureous acid, which becomes sulphuric acid, and itself passes to the metallic state. Though the sulphite of copper is little soluble in water, it is sufficiently so to be rendered sensible by pot-ash, which produces a greenish flocculent precipitate, and by ammonia, which gives it a blue colour. Concentrated sulphuric acid, poured on the crystallized sulphite of copper, disengages from it with noisy effervescence much sulphureous acid in the state of gas, and separates from it a brown red pulverulent matter resembling wine-lees. On adding water, this precipitate

precipitate does not re-dissolve : but being left exposed to the air, without water, it loses its colour, and dissolves in the sulphuric acid. In this experiment the oxygen of the copper is transferred to the sulphurous acid, part of which it converts into sulphuric acid ; and thus the oxide of the copper passes nearly to the metallic state. Nitric acid acts equally on both of the sulphites of copper, disengages sulphurous gas, and nitrous gas, and converts them into sulphate of copper. We see this combination, hitherto unknown to chemists, and which cannot be obtained directly from sulphurous acid and copper, on account of the feeble attraction of this metal for oxygen, exhibits very interesting phenomena, the explanation of which is to be found in the pneumatic theory.

62. The nitric acid is pretty rapidly decomposed by copper, which extricates from it uniformly, without great concussion or violence, and without swelling up, nitrous gas, which is frequently employed in eudiometrical experiments ; either because the tranquil, successive, and in some sort regular manner, in which it escapes during this solution of copper, renders the operation easy and certain ; or because this nitrous gas has been found to be one of those, which answers best in experiments of this kind. It may be conceived, that this property arises from the copper not being so greedy of oxygen, and not absorbing it in such abundance and in so solid a state, as zinc, tin, or iron does ;

does; whence it does not so completely decompose the acid of nitre, and separate from it its radical, or azote, alone, or cause the nitrous acid to be mixed with more or less azote gas, as happens with the metals I have mentioned. It is for the same reason, that the nitric solution of copper affords no traces of ammonia on the addition of lime, while the solutions of the metals abovementioned by the same acid do it so frequently: these, in fact, very often decompose the water at the same time as the nitric acid; but the copper, which does not separate all the oxygen from this acid, *a fortiori* cannot effect the decomposition of water.

63. In proportion as one part of the nitric acid, which is decomposed, yields its oxygen to the copper, this, being reduced to the state of oxide, dissolves in the other part of the acid, which is not decomposed: the solution is at first of a pale blue, and as it were mixed, with a white powder, but soon assumes a more brilliant hue, and becomes perfectly transparent: the copper that remains at the bottom is oxidized of a deep brown or black on its surface. The same solution may be obtained with the oxides of copper, which are extremely soluble in nitric acid. This acrid and styptic solution, being evaporated slowly, yields elongated paralleloiped crystals. If evaporated with less caution, it affords only fine or needled prisms, clustered and compacted together in a sort of radiated bundles, the figure of which it is impossible

possible to determine. Accordingly, some chemists have described them as hexahedral prisms, others as tetrahedral; and some have said, that the nitric solution of copper does not crystallize at all. The nitrate of copper thus obtained is of a brighter blue than the sulphate of the same metal: it is so acrid, and so caustic, that it may be used for corroding excrescences and fungous flesh. It is fusible at 25 or 30 degrees of Reaumur's thermometer: and as it dries on the burning coals, on which it is put, it detonates, or inflames them slightly at its edges. Paper dipped in its solution, and dried, burns with scintillation in a slight degree of heat. The nitrate of copper melted in a crucible exhales much nitrous vapour: some chemists have directed it to be distilled, for obtaining from it the fuming acid: after having given out its water and its acid partly decomposed, it leaves an oxide, of a very deep and very brilliant green on its surface, while at the bottom, where it has been most heated, it is of a chestnut colour. The nitrate of copper strongly attracts the moisture of the air: it is very soluble in water: exposed a long time to dry air, and left to evaporate spontaneously, its solution is de-ficcated, and changed to a green powder.

64. Earths and alkalis in general precipitate the solution of nitrate of copper in a blueish white oxide, which becomes green in the air. Slaked lime, thrown in powder into the solution has the property however, not merely of preserving

preserving the blue colour of the oxide it precipitates, but of enlivening it, rendering it bluer, and remaining combined with it under the form and in the state of *verditer*. England alone has long produced this as an article of trade, which is a colour much employed in the fabrication of paper hangings. Pelletier has described its analysis, and given the mode of preparing it, in the *Annals of Chemistry*. An hundred parts of fine English verditer yielded him fifty of copper, thirty of carbonic acid, ten of oxygen, seven of lime, and four of water. For preparing it he directs us to dissolve copper without heat in diluted nitric acid; to add lime in powder to the solution, and stir the mixture, that the decomposition may take place quickly; to put more nitrate of copper than is necessary to obtain a pure oxide of this metal; to decant the liquor, wash the precipitate well, drain it on a linen cloth, and afterward levigate it on a stone or in a mortar with quick lime, of which from seven to ten parts are gradually to be added to a hundred of the precipitate, which immediately changes the colour from a faint green to a blue; to try the colour of it, by drying a little in the air and in the sun; to use a little water in mixing and levigating it, if it be too dry; and to dry it in the open air. In this operation, it was at first thought, that the oxide of copper, already turned green by the air when exposed to it alone, returned to a blue from a retrogradation of its oxidized state

state, in consequence of the admixture of lime; stopped at this state of oxidation by the help of this earth; and absorbed with it even a pretty considerable portion of the carbonic acid of the atmosphere. But though this partial disoxidation, considered as the effect of the lime on the green oxide of the copper, appeared to remain some time in this state, it was not considered as very durable, since it was found that all paper stained with this verditer at length acquired a greenish tinge, and even became wholly green after having been exposed for some months to the air.

65. A still more speedy disoxidizing effect was admitted in ammonia, when employed to decompose nitrate of copper. At first a pulverulent precipitate of a blueish white is observed, which on the addition of a little more ammonia disappears, re-dissolves, and imparts to the liquor a blue much more intense than that of the former nitric solution. Stahl had said, that this ammoniacal solution, being exposed to the fire, detonates like fulminating gold: but Bergman could not obtain the same effect. Pure fixed alkalis do not operate in the same manner: they neither give a blue colour to the oxide of copper, which they separate from this solution, nor do they re-dissolve it. The alkaline sulphurets and the hidro-sulphurets decompose nitrate of copper, forming with it a reddish brown precipitate. Sulphuric acid decomposes this salt, and forms with it sulphate of copper.

Most of the salts, and particularly the alkaline sulphates, phosphates, borates, and carbonates decompose it. Several metals, iron especially, precipitate its copper in the metallic state, by taking from it the oxygen, for which they have a greater affinity. Higgins has observed, and described in the Philosophical Transactions, Vol. 63, p. 1, a very remarkable phenomenon produced on nitrate of copper by tin. If crystals of nitrate of copper a little moist be put into a piece of tin beat into a little cup, they attract the humidity of the air: the humid part attracts the tin, and colours it brown by precipitating the oxide of copper: heat is generated: a copious nitrous vapour is disengaged; the matter at length takes fire with explosion: and if the tin were very thin, it is torn by the kind of deflagration which takes place in this experiment. We discover here the effect of the great affinity tin has for oxygen, and the energy with which it attracts it, either from the nitric acid, or from the oxide of copper.

66. Such were the notions respecting the properties of the nitrate of copper, that had been adopted from the new principles of the pneumatic system, and from the experiments of Citizen Guyton and of Pelletier on it, when Mr. Proust, in some particular researches, (transmitted to the Institute about the end of the year 9,) proposed several modifications of these notions, and offered some more precise and accurate

curate ideas on the subject of these cupreous compounds. To form a just conception of the result of his labours, we must keep in mind, that he admits but one invariable degree of oxidation in copper, whether burned by the action of air, or by that of acids, or by any of the means employed to unite it with oxygen. It must be remembered, that, admitting solely the oxide of copper with 0,20 of oxygen, or one fifth of its weight of this principle he rejects altogether the distinction of brown, blue, and green oxides, which had been formerly adopted by Citizen Guyton; and which I myself had embraced, as perfectly consonant with all the properties, and all the phenomena, exhibited by copper in its numerous combinations. Though I am not entirely convinced, that there is in fact but one oxide of copper; because this metal constantly changes its colour, and passes in succession from brown to blue, and from blue to green, by oxidizing processes; because by disoxidizing processes it is made to take the same tints in the opposite progression; and because Mr. Proust has not made known the methods of analysis, by which he always found these 0,20 of oxygen in every oxide, which he says he examined: nevertheless, as I am equally unacquainted with the precise results respecting the different proportions of oxygen, existing in the divers oxides, admitted prior to the labours of the able chemist of Segovia, I acknowledge, at least, more accuracy in his new data; and
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admitting with him, that copper oxides only to 0,20 of oxygen, I shall proceed to relate the principal points of his experiments on nitrate of copper and its precipitates.

67. On distilling a nitric solution of copper, according to this chemist, water and the excess of acid are obtained. The condensed salt adheres to the retort in a green, lamellated, insoluble crust; from which a large quantity of boiling water can take up nothing that sulphurated hydrogen will render perceptible. On being heated strongly, this nitrate of copper, with a *minimum* of acid, loses this acid, and is reduced to 0,67 of black oxide. Pot-ash assisted by heat equally reduces it to the state of black oxide, by taking from it its acid. It contains 0,67 of this oxide, 0,16 of acid, and 0,17 of water. The nitrate with excess of acid, on the other hand, contains but 0,27 of black oxide. An hundred parts of copper, treated with nitric acid, and reduced to the state of oxide by the action of heat, afford 125 parts of this oxide: which leads Mr. Proust to affirm, that copper is not burned more by nitric acid, than by other means. Nitrate of copper at the *maximum* of acid yields a precipitate with a small quantity of pot-ash, which passes from blue to green, and which is nothing but nitrate at the *minimum* of acid, or with excess of oxide. If on the contrary we throw the former cupreous salt into pot-ash well diluted, and in sufficient abundance to predominate, we have a bulky precipitate,

prevent me from absolutely admitting his hydrate of copper; a sort of combination of a metallic oxide with water, which is analogous to no other compound yet known, and the termination of which in *ate*, proposed by the professor of Segovia, would perhaps infer, if its existence were proved, too direct a relation to the compounds of the powerful acids. This subject therefore still deserves to be resumed and examined with much care by chemists: for, if their farther researches should accord with those of Mr. Proust, they may be extended to most other metallic substances, which ought to exhibit analogous combinations.

69. The muriatic acid attacks copper, and dissolves it, if it be concentrated, and assisted by heat. During this solution a weak effervescence, and a slight evolution of hydrogen gas, take place. As it cannot be effected without heat, a portion of the muriatic acid flies off in gas; and the first experimentalists who examined the elastic fluids produced during its solutions of different metals, have mentioned this gas only. The water however is decomposed: and the copper appears to be more oxidized, or at least brought to a different state from what it is by the sulphuric and nitric acids, since it assumes a green colour, while it is blue in its combinations with the latter acids. In this way we obtain a solution of a superb green, by which it is distinguished from those of the sulphate

phate and nitrate of copper : and it is procured instantly, without commotion, without heat, without effervescence, on throwing green or blue oxide of copper into muriatic acid, even if a little diluted with water. On evaporating this muriatic solution of copper, it affords when it has become thick, and when it is left to cool slowly, elongated square prismatic crystals, or small long needles, compacted together or in confused bundles, of a very brilliant and very lively grass green. This salt is very acrid and caustic : it melts with a gentle heat : it fixes in a mass on cooling : a very powerful heat, long continued, is requisite to decompose it, and expel the muriatic acid. It strongly attracts the moisture of the air, and soon becomes like a thick oil. It is not alterable by the sulphuric or nitric acid. It emits very copious fumes, when exposed to ammoniacal vapour. The alkaline re-agents decompose it, and precipitate from it an oxide of a blue white, which becomes green in the air. Lime preserves its first tint, and forms with it a fine verditer. Ammonia re-dissolves it into a blue liquid, a little less brilliant however than it makes with the sulphate or nitrate of copper. Several metals, particularly zinc and iron, precipitate from it the copper in a metallic state. The sulphuric and nitric solutions of most of the white metals form with its solution sulphate or nitrate of copper, and white insoluble metallic muriates.

70. To these facts respecting the muriate of
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copper, generally admitted by all the chemists who have turned their attention to it, I ought to add the late observations of Mr. Proust. After having purified and crystallized this salt by means of alcohol, he decomposes it by pot-ash, and nitrate of silver. The first pointed out to him the proportion of oxide; the second, that of muriatic acid. He found in it 40 parts of black oxide of copper, 24 of acid, and 36 of water. According to him, this salt may be distilled to dryness, without undergoing any alteration; but on urging the fire, part of its acid is expelled in the state of oxygenated muriatic acid; and the copper is reduced from 0,25 of oxidation to 0,17, and forms a white muriate of a particular kind. From this single observation of the Segovian professor, may we not be induced to believe, contrary to his own opinion, that copper is susceptible of several degrees of oxidation; that the oxygenated muriatic acid, obtained in the experiment he adduces, is owing to this; and that, if the metal be dis-oxidized in this instance, there is reason to believe, that it exhibits the same phenomenon on many other occasions? The muriate of copper, treated with a little pot-ash, yields a green precipitate, which is muriate with a *minimum* of acid: if the alkali predominate, we obtain the blue oxide, which Mr. Proust terms *hydrate* of copper. This metal treated with the nitro-muriatic acid, furnishes spontaneously a muriate at the *minimum* of acid, in a green powder, which contains, according to this chemist, 79 parts

of black oxide, $12\frac{1}{2}$ of muriatic acid, and $8\frac{1}{2}$ of water. On this occasion he gives the analyses of two native muriates of copper, one of Chili, the other of Peru: the first contains black oxide 76, acid 10, water 12; the second, oxide 70, acid 11, water 18. Treated with fire, and with pot-ash in different quantities, they act precisely as the artificial muriate of copper.

71. The oxygenated muriatic acid oxides copper, dissolves it without effervescence, and forms a green salt similar to the preceding. We know nothing of any combination between oxide of copper and oxygenated muriatic acid, or super-oxygenated muriate of copper: and, on the contrary, we remark, that on distilling common muriatic acid from green oxide of copper, oxygenated muriatic acid is disengaged by the action of heat, as I have noticed in the history of the cupreous sand of Peru, which on distillation, and in proportion as the oxygenated muriatic acid is extricated, leaves an oxide of copper of a brown colour, or nearly approaching the metallic state. This observation has since been confirmed by Mr. Proust.

72. The phosphoric acid is not decomposed by copper; but, when it has remained some time on this metal, it favours its oxidation by water or by the air, and thus forms a phosphate of copper, but little soluble. This salt is obtained immediately by pouring solutions of alkaline phosphates into those of most of the preceding salts. A double decomposition then takes

place: the phosphoric acid fixes on the oxide of copper, with which it forms an almost insoluble precipitate of a greenish cupreous phosphate. The properties of this salt have not yet been examined: we only know, that heated in a crucible with charcoal, it gives a very brilliant grey phosphuret of copper; and that it is this combination which is frequently found in little grains among the residuum left after the distillation of phosphorus, when it is made with phosphoric acid that has been evaporated in copper vessels, as I have already said above. We are equally unacquainted with the phosphite of copper.

73. The fluoric acid easily oxides and dissolves copper. Its oxidation is effected here as with the muriatic acid, by the help of the water, which is decomposed, and yields to it its oxygen. The properties of this combination have not yet been examined. The same may be said of that, which it is capable of forming with the boracic acid. The last is chiefly obtained by pouring solutions of borates into those of copper by almost any of the preceding acids. A greenish precipitate takes place, very little soluble, which all the acids decompose, and from which they take the oxide of copper.

74. The carbonic acid has no action upon copper, either in its state of gas, or in a liquid form. It is readily absorbed, however, by the blue or green oxides of this metal: and this is what happens in the natural oxidation of cop-

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per, in the formation of verdigris, which is merely carbonate of copper, and in that of mountain green, filky copper, and malachite, which are the same salt in different states of condensation, compactness, crystallization, &c. We see, too, with what rapidity this union takes place in the precipitation of different salts of copper by alkaline carbonates, and how much carbonic acid is absorbed by the oxide of copper; since, when it is precipitated, no effervescence takes place. The analysis of the native carbonates of copper proves, that they contain more carbonic acid than most of the other metallic salts formed by the same acid. Mr. Proust has found, that an hundred parts of copper, dissolved in an acid, afforded with carbonate of pot-ash, or soda, an hundred and eighty parts of green carbonate of copper, which contained an hundred parts of copper, twenty-five of oxygen, forty-six of carbonic acid, and ten of water. To prepare this salt of a brilliant and uniform colour, it should be precipitated with boiling water, the vessel should be placed in the sun, and the salt should be washed with great care. The native carbonate of copper consists of the same proportions as the artificial.

75. The metallic acids have a more or less decided action on copper. Scheele has described that of the arsenic acid with considerable accuracy. By digesting this acid on copper with water, a green solution is made, in which there is a precipitation of a blueish white powder, consisting

consisting of arsenic acid and oxide of copper. One part of copper filings being heated in a retort with two parts of dry arsenic acid, they melt easily; arsenious acid is sublimed into the neck of the retort, and there remains a blue melted mass, soluble in water, which precipitates from it a white powder. The alkaline arseniates precipitate all the other solutions of copper of a blue colour. This arseniate of copper fuses in a crucible, with a strong heat, into a brown scoria, which, on being heated with charcoal, yields sublimed arsenic and pure copper. The arsenite of pot-ash, which Macquer termed *liver of arsenic*, poured into a solution of sulphate of copper, forms a precipitate of a very rich green, which Scheele proposed to use as a paint, because it does not change in the air. This, which is called *Scheele's green*, is a true *arsenite of copper*. The following are the proportions recommended by the Swedish chemist for this useful preparation. Dissolve a pound and a half of sulphate of copper in sixteen pints of hot water; pour this hot solution gradually into another solution, equally hot, of a pound and half of pot-ash and ten ounces of arsenious acid in five pints of water: shake the mixture, let it stand to settle for a few hours, pour off the clear liquor from the green precipitate formed; wash the insoluble precipitate well with cold water, then dry it by a gentle heat, and keep it for use. The proportions here given will yield nearly
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one pound two ounces. The waters poured off in this operation must be thrown far from places where animals live, because they hold arsenic in solution.

76. The tungstic acid does not combine with copper unless the metal be oxidized. It precipitates the sulphate of copper white. We know not the combination of the molybdic acid. Citizen Vauquelin, in his discovery of chromé and the chromic acid, found that it precipitated the nitrate of copper of a chestnut-red, the colour of the chromate of this metal,

I. *Action on the Salifiable Bases and Salts.*

77. THERE is no other action or other union between the earths and copper, than that which is obtained by vitreous fusion. It forms a glass most frequently of a brilliant green colour; but sometimes it is of a chestnut-red, or a more or less brilliant brown: this depends solely on the state of the oxide, which is taken for this vitrification. It is almost always for obtaining different shades of green, that it is employed in the manufacture of porcelain, different kinds of earthen ware, and coloured glass.

78. The fixed alkalis, dissolved in water, digested with filings of copper, and then left to become cold on this metal, favour its oxidation. They acquire a light blue tinge, and the copper itself assumes this colour; but very little of it dissolves, and we can scarcely find any trace of
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it in the supernatant liquors : besides, they presently let fall the small portion of oxide of copper, which they dissolve. In these operations we observe, that the contact of air contributes greatly to the oxidation of the metal, as it is very slight, or scarcely takes place, in close vessels.

79. Of all the alkaline substances ammonia has the most decided action on copper. This action has long ago been noticed and described by every chemist. Liquid ammonia, digested with filings of this metal, acquires, when assisted by the contact of air, a brilliant blue colour, of the most beautiful tint. It dissolves but a very small quantity, however, of cupreous oxide. I have observed the phenomena of this oxidation and solution for the space of a year. Having some liquid ammonia standing on copper filings in a small phial, and having frequently uncorked the phial to admit the air from time to time to come into contact with the liquor, I perceived at the expiration of some months, and after the liquor had assumed a brilliant blue colour at repeated times, that the surface of the metal was covered with a blue oxide; the sides of the phial were coated with a pale blue oxide of copper, and its lower part, where the greater part of the copper still remained in filings, exhibited under the slight coat of blue, which covered it, a light brown powder, the surface of which was yellowish: so that the metal appeared to be either in two states of oxidation

tion, or an oxide combined and altered in two different manners. I found, that, when the liquor lost colour in the phial closely stopped, which however it never did so far as to become clear and colourless, this was owing to the precipitation of part of the oxide of copper; and that, when it resumed a deeper tint in the air, this was because it absorbed from it a portion of oxygen, and the copper became soluble in the ammonia, and acquired by this solution the fine blue colour which characterizes it. Without alternately exposing this liquor to the contact of air, and withholding it from it, if it be taken at any given degree of colour, and inclosed in a bottle which it fills completely, it loses nothing of its tint, but remains perfectly in the same state in which it was at first. This was the case in the experiment of Mr. Wafferberg, who put this light blue solution into a tube blown with a bulb which he completely filled, and sealed hermetically. In nine months this liquor underwent no alteration of colour; the reason of which appears from what I have said.

80. On slowly evaporating the ammoniacal solution of copper, the greater part of the ammonia separates in the form of gas; a small portion only remains fixed with the oxide of copper, and several chemists say, that it will yield transparent crystals of a fine blue colour, similar to the native azure of copper. But there is a great difference between these two substances: and some modern chemists assert, that
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the pure ammoniacal solution of copper never crystallizes; mixtures of acid salts of copper, precipitated and re-dissolved by ammonia, which in reality furnish crystals of triple salts, having been confounded with it. In fact this solution in a pure state, dries on exposure to the air, and becomes a more or less brilliant green, in proportion as the dissipation of the ammonia leaves the oxide bare, which gradually absorbs the carbonic acid of the atmosphere. The same ammoniacal solution of copper, saturated to the highest degree possible, leaves only some vestiges of a blueish grey precipitate with acids: and these, if ever so little in excess, occasion its fine blue colour to disappear entirely, and give it a very pale green.

81. The green oxide of copper, brought into contact with ammonia, instantly turns blue. This action, which was supposed to be a commencement of disoxidation, but which may be nothing but a simple union of ammonia, is much stronger, and proceeds much further, if heat be employed. In this case azote gas is extricated: the hydrogen of the ammonia attacks the oxygen of the oxides, and forms with it water: the oxide changes to brown, and ultimately, even to the complete metallic state. Citizen Berthollet employed this experiment to discover the nature of ammonia, and to determine the proportion of its principles, by that of the azote evolved in gas.

82. Though copper easily rusts and becomes covered with verdigris by the action of saline matters

matters with which it is moistened, or in which it is immersed, it has, nevertheless, a very weak action on most of the salts. It does not decompose the sulphates either by heat or by cold. When left, if boiled with a solution of alum, it is oxidized and partly dissolved on account of the excess of sulphuric acid contained in the salt. It appears also, that the sulphate of copper which is formed in this case, unites into a triple salt with the sulphate of alumine and pot-ash, as it unites with the sulphates of zinc and iron equally into triple salts. It is on this account that the alumine, precipitated from alum, the solution of which has remained for some time in vessels of copper, has a slight blue tinge.

83. The nitrates, and especially that of pot-ash or common nitre, burn copper, and oxidate it, but without sensible inflammation or detonation; only slight scintillations take place when the copper is fused and red, or when the copper is thrown in fine filings upon fused nitre in a crucible. By this process, there is formed a brown oxide of copper mixed with pot-ash; when we wash it with water, the alkali is dissolved, and there remains only pure oxide of copper, which is prepared in this manner for several of the arts, and especially for the fabrication of enamels. This kind of oxide fuses easily into brown or chestnut-coloured glass.

84. It is asserted in many books of Chemistry, that the solution of muriate of soda, dissolves copper

copper by ebullition : Heller has even computed that eight ounces of salt had dissolved twenty grains of copper ; Wallerius has remarked, that this metal, fused with the muriate of soda and afterwards exposed to the air, quickly became covered with verdigris : and every one knows that salt, when kept for some time and moistened in copper vessels, very easily covers them with verdigris ; but this effect is owing to the water and the air rather than to the salt, for this last does not appear to undergo any alteration in its principles.

The muriate of ammonia is decomposed by copper with the aid of heat ; hydrogen gas and ammoniacal gas being disengaged ; as the product there remains a muriate of copper. The liquid ammonia which also forms a part of it, on account of the water contained in the salt, is always of a blue tinge, because of a small quantity of oxide of copper which it carries with it. The solution of muriate of ammonia, acts also upon copper ; and it assumes a blue colour whenever it is suffered to remain in vessels of this metal. The oxide of copper equally decomposes the muriate of ammonia by distillation, and even affords carbonate of ammonia, if it contained carbonic acid.

In pharmacy, two preparations are made with the ammoniacal muriate and copper. The one, which bears the name of *Æns Veneris*, or *cupreous ammoniacal flowers*, is nothing more than this salt, coloured with nearly a sixtieth

of its weight of green oxide of copper in two earthen pans placed one above the other, or in a capital of glass, covering an earthen pot: it is evident that but very little ammoniacal muriate is decomposed; and that which sublimes, carries with it the small quantity of muriate of copper that has been formed. The other pharmaceutical preparation is called *Celestial water*, on account of its fine blue colour. Any quantity of lime-water is suffered to remain for ten or twelve hours, with half its weight of muriate of ammonia, in a copper basin. The small quantity of ammonia disengaged by the lime, dissolves some particles of copper, and gives to the whole of the liquid the blue cast with which this solution is constantly tinged. We may prepare the celestial water in a glass vessel, by adding a small quantity of copper-filings or shavings, or even of the oxide of this metal, to lime-water and muriate of ammonia.

85. The super-oxygenated muriate of pot-ash burns very quickly, and even inflames copper, though indeed without kindling it by percussion, but merely by the contact of a burned body, especially red-hot charcoal.

The phosphates, the fluates, the borates, and the carbonates, exert no action upon copper except by the water in which they are dissolved; and this action, like many of those that have hitherto been described, is greatly aided by the contact of the air.

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of these remedies, which are always dangerous and rarely beneficial: even externally, they do not prescribe them except with the greatest circumspection.

88. Besides the varied and multiplied uses of copper in the metallic form, several ores and preparations of this metal are employed in a great number of the arts. The pyritous sulphurets serve for the preparation of the sulphate of copper, by their spontaneous efflorescence and their lixiviation: it is also prepared by burning a mixture of sulphur and of copper. The malachites are cut and polished for trinkets; copper is continually alloyed with zinc and tin, for making brass, casting statues, bells, pieces of artillery, &c. Its different salts and oxides enter into the preparation of colours for painting; of the baths, the preparations and mordants for dyeing; of enamels and glazings for pottery and porcelain; and of coloured glasses.



ARTICLE XX.

Of Silver.

A. History.

1. THE four last metals which have been examined, belong to the fourth genus of these bodies, to those which are at the same time sus-

ficiently ductile and easily oxidable; - the three last, whose history remains to be given, form the fifth and last genus of these bodies, by their properties of being eminently ductile and oxidable with difficulty: accordingly, on account of these two characters which they combine in a high degree, they have always been distinguished from all the other metallic matters by the expression of *perfect metals*. The alchemists formed very singular ideas concerning them. They considered them as the most metallized substances, as the last and most perfect state of metallization, as the metals upon which nature had exhausted all her efforts; poured out, as it were, all her power, after having tried it upon all the preceding metallic substances: accordingly, in their art, always chimerical, but always replete with hopes, they pretended to imitate nature, in perfecting, by means of persevering and long continued labours, the imperfect metals; by adding to them, on the one hand, what they wanted, and taking from them the kind of acrid or foreign substances of which they had too much; by maturing them, in some manner, by their philosophic incubation.

2. Silver, which was known by the nations of antiquity, and the discovery of which dates itself earlier than the most ancient records of mankind, soon became, by its scarcity, its beauty and all its useful properties, the object of the researches of a great number of artists and men of science. It is not astonishing that

men who had caused the metallic substances to assume so many different forms, and who so frequently imitated in alloys the whiteness and several of the properties of silver, harboured from a very remote period the idea of creating this precious metal by art. When they compared it with the other white metals, it seemed to them to differ from it only in some qualities, and that it would not be impossible to procure it free from those qualities. Not discouraged by their first unsuccessful attempts, in proportion as this precious metal became amongst mankind the representative of all other objects, of all the productions of industry, and even of those of genius, the alchemists redoubled their efforts; and though their experiments and their laborious researches have not had all the success which they expected from them, they have not been entirely lost. It is from these unfortunate trials, accumulated by the labours of ages, that chemists have derived the facts which they have employed in its history, and they have had, as it were, nothing more to do than to arrange in a methodical order and clearly to describe the phenomena which this metal had presented in the tortures of every kind to which alchemists have subjected it.

3. Whilst the alchemists, who called silver *Luna* or *Diana*, qualified it, even by the sign which they consecrated to it, as a kind of semi-gold, which they represented by two semi-circular lines put together in the same direction, with

the horns turned to the left; so that nothing more was necessary than to turn back the interior curve, and unite it with the exterior, in order to form the circular figure, or characteristic sign of gold, to which they believed it to be in fact very nearly related, since it was only required to develop one of its parts in order to cause it to pass into the state of gold, the last stage of metallic perfection; the docimastic and metallurgic artists, more wise and more useful, laboured incessantly to purify silver and completely to separate it from all the other metals, to acquire a perfect knowledge of it in its state of purity, to extract it without loss from the great number of minerals in which nature has placed it, to alloy it with other metals in order to add to their useful properties, and to cause these metals to acquire in some of its good qualities. Their important labours, followed by a degree of success which has multiplied silver in society, and has extended its numerous uses, have been no less useful to the chemists in constructing the system of their science. The pharmaceutical operations themselves, though they have been much less numerous upon silver than upon all the other preceding metals, have served to increase the stock of chemical knowledge concerning this metal; and it is from the whole of these labours that the history of this important metal has gradually been formed.

4. Silver has particularly occupied a great number of chemists. Henckel, Cramer, Lehman, Kunckel, Hellot, Tillet, &c. have considered it as assayers or metallurgists; Bergman has carefully examined its ores by analysis in the humid way; Lewis has written a particular treatise upon it, especially with respect to its uses in the arts. The French pneumatic chemistry has remarkably elucidated its properties; it was by its aid that Van Marum found the means of burning it by means of the fulminating electric shock, that its oxidation by means of the focus of burning mirrors has been determined, which was timidly suspected and announced by Homberg and Macquer; it was this theory which explained its difficult combustion and its easy reduction, and led Citizen Berthollet to the discovery of the singular and most astonishing preparation of fulminating silver. While its properties have been better known and better explained than they had ever been before, they have equally served to enlarge the dominions of science and the pneumatic doctrine.

B. Physical Properties.

5. SILVER is of a fine white colour and of an extremely lively brilliancy. Whether burnished or otherwise, this metal is the most beautiful that is known, at least in the opinion of most men. In general it pleases more than any other.

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metallic substance. There is no metal that approaches it in lustre; it holds only the fifth rank amongst the metals with respect to density and specific gravity; it follows after platina, gold, tungsten, mercury, and lead. Its weight is represented by 10,474, according to Citizen Guyton. Muschenbroeck estimated it from 11,091, in one of the most dense specimens, to 10,253 in one of the lightest, and Boerhaave from 10,535 to 11,087. These differences from the *minimum* to the *maximum* depend upon the state of fusion and that of forged silver.

With respect to its hardness, it has been placed between iron and gold; it is augmented by the action of the hammer or by pressure. Its elasticity is pretty considerable, and in this respect it is intermediate between gold and copper. It is one of the most sonorous metals, and when struck upon, it emits a very acute sound; I have also remarked in the history of the alloys of copper that is sometimes added to bell-metal.

6. The ductility of silver is one of its most marked properties; it follows immediately after gold and platina. It is made into leaves so thin that they are easily wafted away by the wind, and into wires of extreme tenuity: accordingly, the example of silver is used in Natural Philosophy, in order to prove the divisibility of matter. A grain of silver may be sufficiently extended, and at the same time sufficiently firm to make an hemispherical vessel

to contain an ounce of water, and a wire 400 feet in length. It is upon this amazing extensibility that the art of gold and silver-beating is founded. It holds the second rank after gold with respect to tenacity, or resistance against breaking. A wire of this metal, one tenth of an inch in diameter, supports a weight of 270 pounds before it breaks. This wire is considerably lengthened before it breaks. Silver, is hardened by all kinds of pressure; but it easily acquires its former ductility again by the action of fire, or by annealing.

7. Silver is a very good conductor of caloric, and becomes heated very quickly. Its dilatability by fire is a little inferior to that of lead and tin, and superior to that of iron, when silver has been dilated by heat, and we urge the fire till it is heated to whiteness or incandescence, it softens and runs. Its fusibility has been estimated by Mortimer at 1000 degrees of Fahrenheit. Citizen Guiton estimates it at 23 degrees of Wedgwood's pyrometer. When silver has been fused and suffered to cool slowly, it presents at its surface figures similar to net work and fern-leaves which announce a very marked crystallizability. On breaking it we find a granulated texture which possesses the same property. Mongez the younger, and Tillet, by suffering a liquid portion to run off from a large mass of fused silver, have obtained it crystallized in quadrangular or octahedral prisms, and it affects the same form in nature, as I shall show hereafter.

8. When

8. When silver is fused, if we augment the quantity of caloric, or if we heat it still more, it at last actually boils and is reduced into vapour: it is on this account that silver condensed in grains, or in forms resembling kidneys, are found in the chimnies of mints or silver-smith's shops. When silver is well fused, its surface is so brilliant by the light which it reflects that it appears to emit sparks; this phenomenon is also termed the brightening *lightning* in the assayer's art. The silver is seen to rise in vapour, boiling and agitating itself with a circular motion, when it is kept for some time fused in the focus of a burning glass. If we expose to this vapour a plate of gold, it quickly becomes covered with a layer of unpolished silver, which may be burnished by pressure. Citizen Darcet, having exposed pure silver in crucibles of porcelain to the fire of the manufacture of Sevres, constantly remarked that at this violent heat the metal was dilated and swelled with such force that the crucibles were broken.

9. Silver is a very good conductor of electricity and galvanism, and it succeeds very well in both these two kinds of experiments. It has no sensible taste nor smell; neither does it produce any effect upon the animal economy, and though it cannot be considered as dangerous to the health, it must, nevertheless, be reckoned amongst the number of perfectly inert

inert substances, destitute of any medicinal property.

C. Natural History.

10. NATURE presents silver neither in such abundance, nor in so many places, nor in such large masses as most of the other metallic substances. Even the number of species that can be distinguished amongst the ores of this metal, is infinitely more limited than those which are admitted in most of the other metals. The mineralogists who have hitherto considered its varieties as species have moreover committed another error; namely, that of having too closely followed the errors and prejudices of the miners. These, considering as ores of silver all those ores that are capable of affording this precious metal; of whatever nature they may be, have qualified by this name the real ores of cobalt, of zinc, of lead, &c.: and hence their very voluminous works contain many double appellations, and have obscured the natural history of silver.

11. Well convinced of this source of error, I have adopted only five species of ores of silver sufficiently different from one another, as they have been designated in the Outline of mineralogy by Citizen Haüy; and I distinguish with him:

A. Native

- A. Native silver;
- B. Antimoniated silver;
- C. The sulphuret of silver: these three contain the silver in the metallic state;
- D. The sulphuret of oxide of silver and of antimony.

E. Lastly, the muriate of silver. I shall follow this division of five ores of silver, to which some pretended species will be referred as varieties. These five species present no oxide of silver in an insulated state.

12. The *native silver*, distinguishable by its colour, its ductility, and its weight, is frequently dull grey, and blackish; but friction restores its lustre. It is found in many varieties of form; sometimes in masses irregularly rounded, or in kidneys: it is frequently in capillary contorted fibres, in plates, in reticulations like spiders-webs, in dendrites, in octahedrons grouped together, in fern-like leaves, in cubes. It is most frequently spread upon a quartzose gangue, and sometimes it is found in fat earths. It has also other ores for gangues, especially those of cobalt. It exists particularly in Peru, in Mexico, in the interior of Africa, at Konfberg, in Norway, at Johann-Georgen Stadt, and at Ehrenfriedersdorf, in Saxony, at Sainte-Marie, at Allemont, in France. Though this native metal is properly placed in this first species, it is, however, to be remarked, that the silver does not exist very pure in it, and that some varieties of it might be distinguished as alloys.

alloys. In fact, the native silver frequently contains gold, or copper in intimate combination. We ought not, indeed, to confound with this natural alloy the mixture of silver with the molecules of other metals; a mixture which is then only accidental, being susceptible itself of many modifications, and cannot be reckoned to constitute varieties in mineralogy.

13. The *antimoniated silver*, or white antimonial ore of silver of Romé de Lisle and of most mineralogists, very much resembles native silver by its colour and lustre. Though its colour is frequently altered by a yellowish or reddish tinge, or its surface covered with a blackish and dull pellicle, the slightest fracture causes its brilliancy to re-appear, which sometimes equals that of burnished silver. Its lamellated texture and brittleness distinguish it from native silver. Its specific gravity according to Citizen Haüy, is 9,440. It is found in fluted prisms which approach to the regular hexahedron. Though Deborn indicates this ore as a combination of silver, of arsenic, and of iron, Bergman has found in it only silver and a little antimony, which he even considered as accidental. Citizen Vauquelin, in assaying a fragment by the blow-pipe, found in it indications of antimony, and obtained a button of pure ductile silver, which formed more than three-fourths of the totality of the ore. Citizen Haüy found, according to the calculation of the specific gravity of the *antimoniated silver*,

ver, and to that of the pure silver and antimony, that this weight indicated nearly four for the silver and one for the antimony; and it appears that the proportion is not very different from that which the ore furnishes by analysis: it is very evident that this ore is also a species of alloy.

14. *The sulphuret of silver* is what the mineralogists have termed *vitreous ore of silver*. It is generally in the form of a cube or of an octahedron, either intire or with angular facets; there is also a variety in dodecahedrons with rhombic planes. This ore may easily be cut with the knife. Its colour is generally a blackish metallic grey, sometimes brown, greenish, or yellowish. It easily fuses. By a mild heat, the sulphur is dissipated without fusion, and the silver assumes, by mere softening, and without running, the form of filaments or vegetations. It is frequently found mixed with other ores of silver. It gives from seventy to eighty-four parts of silver in the hundred. This metal is combined in the metallic state, with sulphur, sometimes it is mixed with native silver, which rises from it in the form of dendrites, and intermixed with red silver ore.

15. *The sulphuret of oxide of silver and of antimony*, is the red ore of silver, or simply the *red silver* of mineralogists. This ore is of a deep red colour; sometimes transparent, sometimes almost opaque, frequently brilliant like steel at its surface. Its primitive form is the rhomboidal

rhomboidal dodecahedron which produces several varieties by the laws of decrease. It is found in almost all the places where silver is abundant, but especially at Freyberg in Saxony, &c. It has long been considered as silver mineralized by arsenic, and even as a real arseniate of potash; Bergman has even given its proportions. Mr. Klaproth was the first chemist who announced, according to a more exact analysis, that it contained sulphur and antimony combined with the silver. Citizen Vauquelin has resumed this work, and has given in the *Journal des Mines* (No. 17, *pluviose an. 4*), a very exact and well-conducted analysis of this mineral. He has shown that it was formed of sulphur, antimony, and silver, both in the state of oxides; that it contained no sulphuric acid, as Mr. Klaproth had believed, but that this acid was formed either by means of heat by the union of a small quantity of the oxygen of the metals with the sulphur, or by the combustion of a small quantity of the latter by the aid of the nitric acid employed in this analysis. He treated it by the nitric acid, which dissolved its silver without disengagement of nitrous acid; afterwards by the muriatic acid, which dissolved the antimony and left the sulphur separate. He also treated it with caustic potash in solution; this dissolved its antimoniated portion with a small quantity of sulphur. From his Analysis it results that the red silver contains silver from 0,54 to 0,57, antimony

timony from 0,15 to 0,16; sulphur from 0,15 to 0,17, and oxygen about 0,12. It sometimes contains a little arsenic, which does not amount to more than 0,02. Each of the metals that compose this ore has been particularly obtained in the metallic state. The author concludes from his investigations, that the red silver is a quadruple combination of silver, of antimony, of sulphur, and of oxygen; that the oxide of antimony exists in it in a state approaching to that of Kermes, that it, however, wants a little oxygen in order to render it well soluble in the alkalis, in which it does not become so unless by the aid of that which the silver affords to it; that, in this latter case, it becomes black, opaque, and capable of yielding nitrous gas with the nitric acid; that sometimes the red silver is naturally in this state of inferior oxidation, opaque, and soluble in this acid, with a disengagement of nitrous gas. He also draws this general important conclusion—that the metallic sulphurets are opaque, striated and metalliform, though brittle, and that the sulphurated metallic oxides are transparent, as it were vitreous; and that the different casts which these compounds present, from perfect transparency to complete opacity, depend immediately upon the various quantities of oxygen with which these bodies are combined. It is very evident that Citizen Vauquelin has rendered the chemical history of this mineral much more precise and clear than Mr. Klaproth, the
author

D. Assays and Metallurgical Operations

18. THE assay of the ores of silver is one of the most interesting that can be made, on account of the price of this metal. It must vary according to the different nature of its ores. If it be native silver, after having pounded and washed it, we may agitate this metal with running mercury, which dissolves the silver by a strong trituration; we express this amalgama in order to separate from it the exceeding portion of mercury: we afterwards distil the amalgama; we heat it in a crucible in order to volatilize the mercury; and the silver remains pure. The antimoniated ore of silver, and the sulphuret of silver, must be strongly roasted, in order to separate from them the antimony and sulphur; they are afterwards fused with a proportionate quantity of alkaline flux; it may be treated nearly in the same manner as the antimoniated and sulphurated oxide of silver, as well as the red silver, the sulphur and antimony of which are taken away by the alkali, while the insulated silver is fused.

19. In all these cases the silver is not pure, and as it is of great importance to obtain it in this state, a process is employed which forms the principal basis of the assay of this metal, as it separates from it the foreign metals, the copper, the iron, &c. and leaves it perfectly insulated

lated and alone. This process is founded upon the property which lead possesses of becoming oxidated and carrying off in its consequent oxidation and vitrification the metals foreign to the silver, whilst this experiences no alteration. In order to put it in practice a flat vessel is employed, formed like a small cup, which is called a cupel. This vessel is made of the powder of calcined bones steeped in water, and beaten into a brass mould. This porous matter absorbs the vitrified oxide of lead with great facility. The silver which we wish to purify on the cupel, is placed upon the basin of this vessel, inclosed in a plate of lead, generally weighing twice as much as the silver. This vessel is then introduced under a kind of earthen oven, supported by iron bars in the middle of a square furnace, called the cupelling or assay furnace. Ignited coals surround the muffle, without penetrating into its internal part, because it is perforated only towards its bottom and its sides, so as not to permit the combustible matter to fall into the oven itself. Its thin sides soon become heated to redness. The lead and the silver placed in the cupel are fused, and form a fluid alloy, which, by the continuance and energy of the fire, suffers the lead to be gradually oxidated, volatilized, and vitrified. The fire is managed in such a manner as not to let the fused matter become too strongly red, nor the lead to sublime too rapidly, or soak too quickly into the cupel: for in this case

it does not carry away exactly all the oxidable matters contained in the silver; care is also taken not to heat it too low, in order that no portion of lead may remain combined with the metal. For this purpose ignited coals are placed before the aperture of the muffle, in order to heat it equally throughout. When we observe with attention what takes place in the basin of the cupel, we see the alloy become agitated, burn at its surface, present a kind of drops of spots of a different red cast which always diminish in proportion as the oxidable metals are sublimed or penetrate into the pores of the cupel. When the operation draws near its termination, the pure silver which begins to appear, shines at some points with a brighter lustre than the alloy; the brilliant part extends from the margin to the centre; at last the whole clear surface of the silver presents, at the moment when the last particle of lead is disengaged, a kind of flash, which is called the brightening. The assay is then completed. The cupel is gradually withdrawn from the bottom of the muffle where it was placed, in order to approach it proportionately to the less hot part, and, yet not to let it cool too suddenly: for in this case the button of silver becoming immediately fixed and greatly condensed, compresses the still liquid portion, and sometimes expels it with an explosion; an accident which disperses part of the metal in globules which are seen upon the basin, and which is called (in French) *coupelle perissée*; because

because it does not merit much confidence, and must be commenced anew. Nothing more is afterwards required than to clean the button well when it is round and intire, to brush it, in order that no foreign matter may be left upon it, and to weigh it in very accurate scales. It is unnecessary here to mention that the portion of silver upon which the cupellation has been performed has been also weighed at first with great accuracy. In order to state the degree of fineness, or what quantity of foreign matters have been taken from it by the oxidation and vitrification, the mass which has been taken is divided into decimal or centesimal parts, which enable us to appreciate the smallest quantities of the alloys; for it is easy to conceive that the operation of cupellation is employed upon silver artificially alloyed, as well as upon this metal extracted from its ores. Previous to the introduction of the Republican weights and the new measures into France, the quantity of silver subjected to cupellation was supposed to be divided into twelve parts which were called *deniers* (penny weights): if it had lost a twelfth of its weight, the silver was said to be of eleven deniers (eleven penny weights fine). After this operation the cupel loaded with glass of lead, mixed with the copper or foreign metal which existed in the silver, is very heavy, and generally tinged with a greenish cast by the cupreous oxide. These oxides usually carry off a small quantity of silver, which, however, is so little

as not to influence the accuracy of the assay and the purity of the button of assay, which is the denomination given to the silver obtained by the cupellation. However small this quantity of silver may be, it is not lost, but methods are known for obtaining it in laboratories where a large series of these operations are performed. For this purpose all these cupels thus charged with glass of lead, are pulverized: their metal is reduced by means of black flux; this lead is subjected to a cupellation again upon a larger scale, and in this manner the greater part of the silver which it contains is extracted. In order to be certain of the accuracy of the assay, it is usual to cupel also particularly the lead which is employed in it, and if it affords a small globule of silver, which is called *the witness* its weight is carefully subtracted from that of the returned button which is obtained. Cupelled silver, well separated from the oxidable metals, may contain gold. It will be seen in the history of the latter metal in what manner it is separated from it, and its proportion determined. Sometimes bismuth is employed instead of lead for making the cupellation; it succeeds as well as the latter; but there is no other that can be used for this operation; no other metal can supply the place of either of those two, which are very fusible, oxidable, and vitrifiable. All the others remain more or less abounding in sil-

ver, swell, decrepitate, form prominent scorizæ, masses resembling funguses and vegetations, and disperse the silver upon the cupel.

20. However exact, and however well adapted for the knowledge of the ores of silver, the different preceding processes, in the dry way, may be, they are not sufficient for enlightened chemists, and can never supply the place of a real analysis of these ores. Bergman, Klaproth, and Vauquelin, have successively given very good methods for ascertaining the different states of native silver, and for analyzing its ores. However, some corrections are required in what Bergman has laid down concerning exact assays, in his Dissertation on Humid Assaying. Native silver contains gold or copper, or both these metals, at the same time; the silver and the copper easily dissolve in the nitric acid; the gold remains in a brown or black powder at the bottom of this acid; the copper is precipitated by means of iron; but as this also separates a portion of silver, I advise to precipitate the latter by means of copper, collecting and weighing it with care; what will be wanting of the weight of the ore assayed will belong to the copper, deducting the portion of gold, if it has been precipitated from it in powder in the solution.

21. Antimoniated silver is assayed, and both its nature and its proportions easily ascertained, by means of the nitric acid, which dissolves the first metal and oxidizes the second in a white powder

powder insoluble in this acid, or by means of the nitro-muriatic acid, which, when employed in sufficient quantity, dissolves the oxide of antimony which it forms, and leaves the silver precipitated in muriate of silver. We may also employ the action of the blow-pipe, which sublimes all the antimony into white oxide, and leaves the silver pure and ductile. I also propose detonation with nitre in a well-closed vessel; all the antimony is oxidized, and the silver is fused, and collected at the bottom of the crucible. This process may be proper for several other ores of silver.

22. The sulphuret of silver, well pulverized, is treated by ebullition, in twenty-five times its weight of nitric acid a little diluted. This is repeated several successive times, till the whole of the silver is dissolved, and the sulphur remains pure at the bottom of the solvent. The silver is precipitated by the muriate of soda: 130 parts of this precipitate answer pretty exactly to 100 of this metal. The supernatant liquor contains the metals foreign to the silver; they are separated by the prussiate of pot-ash, or by the carbonate of soda, or by the aid of iron or zinc.

23. We have already seen in what manner Citizen Vauquelin succeeded in determining the nature and the proportions of the red silver, or sulphurated oxides of silver and of antimony. The nitric acid, the muriatic acid, and fixed alkali, are the three solvents which he has employed

ployed with the most success; the first for dissolving the silver, the second for taking away the oxide of antimony, and the alkali for ascertaining the presence of the sulphur. Bergman was in a mistake respecting this ore, when he represented it as especially containing arsenic. His method, being illusory in this respect, ought not, therefore, to be presented here. Neither is it requisite for me to give an account of his processes for analyzing the white ores of silver, the antimoniated sulphureous ore, as I have spoken concerning the humid assay of those ores in the article concerning copper.

24. With respect to the muriate of silver, if it be mixed with sulphate of silver, it is treated by the muriatic acid, which decomposes this salt and leaves its sulphuric acid dissolved; the quantity of this is determined by the nitrate or the muriate of barites, and by the weight of insoluble sulphate that is obtained. The muriate of silver is treated with twice or thrice its weight of carbonate of soda in a crucible, or in the cold by trituration with the carbonate of ammonia, water and mercury: this last process of Margraff affords muriate of ammonia dissolved, and an amalgam of silver. I shall speak of it again hereafter, when treating of the factitious muriate of silver, which the natural resembles in all its properties.

25. There are some resemblances between what has been said concerning the assaying of silver by fire and the treatment of the ores
of

of this metal upon the large scale. Three general methods are followed for extracting silver from the minerals that contain it. The one consists in triturating them with running mercury in mills constructed expressly for the purpose; the amalgam thus produced is well washed in order to separate from it all the earthy gangue; it is then expressed through skins in order to cause all the still liquid mercury to run off; and is afterwards distilled in a crucible of iron. This process of amalgamation is especially employed for minerals that are very rich in native silver: thus the Spaniards transport their mercury from Almaden into Peru, for the purpose of treating the ores of that country. For some years past, in consequence of the exertions of Baron Born, it has been practised upon several of the ores of Hungary, with the addition of the action of several other matters proper for separating at the same time the other foreign substances combined with the silver; but this process has not yet arrived at such a degree of perfection as to be capable of entirely supplying the place of those for which it has been substituted.

26. The ores of sulphurated silver are roasted, and afterwards fused with lead in order to be refined by cupellation. As to those which contain only a small quantity of silver, they are fused, without previous roasting, with other pyrites: it is to be observed, that these are almost always grey copper ores; there then results a
kind

kind of matt, which is called the first fusion; it is treated by eliquation, and the argentiferous lead which is thus produced is cupellated, in order to obtain the pure silver from it. The cupellation on the large scale, which is almost always the ultimate term of the operations which are performed upon the ores of this metal, differs from that which is practised upon a small scale, in the circumstance that upon the bottom of a large furnace, hollowed into a basin, and charged with porous ashes capable of receiving and absorbing a portion of the oxide of lead, the alloy of this metal and of silver is quickly and violently scorified by the blast of bellows, which, in proportion as the lead is oxidated and vitrified, drives away the small scales of this oxide towards the passages of the litharge, as I have described in the article concerning lead.

E. Oxidability by the Air.

27. PURE silver, when exposed to the air, remains in it without alteration except with respect to its polish and brilliancy; it becomes less shining and a little tarnished at its surface, but without being oxidated. We ought not to confound the kind of covering or stratum of a deep blue colour, which is formed upon old silver plate exposed for a long time to the contact of several gases mixed with the air, a stratum, which according to the examination of it instituted by Mr. Proust is merely sulphuret of silver.

silver. Silver has long been believed to be perfectly indestructible by the contact of the air, even when aided by a very intense heat, and on this account it was ranked amongst the perfect metals. Several chemists, and especially Junker, had advanced that by treating silver by a long reverberation, after the manner of Isaac the Hollander, and in a furnace where the flame circulated above the metal, the silver was at last converted into a vitriform oxide. It has even been added, that when united with mercury and divided by this liquid metal, it was oxidized by the processes which are usually employed for converting mercury into red oxide; and this is not improbable.

28. Many experiments made since the assertion of Junker, and by different processes, have proved that silver is really oxidable, but only that it is much less so, and with much greater difficulty than the other metals. Macquer was the first who remarked this oxidation by exposing silver in a crucible to the intense heat of the furnace of Sevres, twenty successive times. At the last time very sensible traces of oxidation were perceived, and a vitrification of an olive colour. The same phenomenon, or one analogous to it, has been observed by Citizen Darcet in a crucible of porcelain, in which the silver had been exposed to the same heat of the furnace of Sevres; at the same time that the metal swelled and broke the crucible, the portion which had run out over its sides was oxidated and vitrified into

into a yellow mass. Macquer never failed to observe, when treating silver in the focus of a burning glass, that after a long incandescence it became covered with a white powder which formed a stratum upon the support of the silver. Homberg, in the first experiments with the burning glass of Tschirnhausen, had made the same observation upon silver and upon gold. It cannot be doubted that these facts indicate a marked oxidation of the silver, and that they become more strong and conclusive, when joined with the new experiments of which I am about to give an account.

29. It is to Citizen Van Marum, who has made so many valuable researches respecting the effects of electricity with the grand machine of Teyler, that we owe the knowledge of the combustion, and even of the inflammation of silver. By passing the electric shock from a battery through a wire of this metal, the wire is suddenly reduced as it were into powder with a greenish white flame, which passes with the rapidity of lightning, and the oxide manifestly formed in this operation is dissipated in smoke. If we perform the same operation by wrapping up the wire or fixing it upon white paper, it attaches itself to it in a very fine powder of a greenish grey colour, so fine and so adherent that it resembles smoke, or a light covering which cannot be separated from it again. It is impossible here to doubt either of the state of oxidation of the silver, or of its combustibility, because the pheno-

phenomenon is constantly accompanied with flame. We may attribute this effect, which is not produced by ordinary fire, however intense it may be, to the extreme division of the metal by the electric shock, and to the high temperature produced by the electric commotion in the body which is exposed to it. A stroke of lightning upon silver wires and silver furniture produces exactly the same phenomena, and is followed by the same results.

50. The oxide of silver formed by these different processes, and which is so difficult to be obtained, is likewise extremely easy of reduction, because the silver adheres to the oxygen very weakly. Though the presence of this body augments its weight, changes its properties, and especially renders it acrid and caustic, nothing more is required than to expose these greenish or yellowish grey oxides to the contact of the solar rays, in order to make them assume a darker colour, become black and approach to the metallic state. When we heat them in close vessels and with the pneumatocchemical apparatus, we obtain from them pure oxygen gas, and easily convert them into the brilliant and ductile metal by fusing them in a crucible.

F. Union with the Combustible Bodies.

31. Silver unites with almost all the simple combustible bodies, except azote, hydrogen, carbon, and the diamond. Hydrogen and carbon decompose its oxides quickly and easily, sometimes even without requiring the aid of lead: in this manner hydrogen gas, received upon paper or silk, impregnated with solutions of silver in the acids, separates the oxide from them in the metallic and brilliant state. Carbon produces the same effect at the temperature of ignition.

32. Pelletier was the first who gave an account of the combination of silver with phosphorus. One part of silver in filings, treated in a crucible, with two parts of vitreous phosphoric acid, and half a part of charcoal, yielded by the reduction of the acidule of phosphorus, and by its union with the metal, a phosphuret of silver which had acquired one fourth of the primitive weight of the silver, and was white, granulated, crystalline, brittle, and capable of being cut with a knife. When phosphorus was thrown upon silver heated to redness in a crucible, the metal was immediately fused, and the phosphuret formed remained in quick fusion; but as soon as it became fixed at its surface, a large quantity of the phosphorus flew out with a great explosion from the mass, and at the same instant the surface of the metal became covered with protuberances.

silver, and forming with it a particular alloy, and yet but very few of these alloys are useful or employed.

Arsenic unites with silver, and deprives it of its ductility : this alloy is yellowish without, and of a dark grey in its interior : when it is exposed to the fire, the arsenic sublimes, and the silver remains pure and ductile. Instead of employing this brittle metal, the vicinity and the contact of arsenic with silver is avoided as much as possible.

No alloys of tungsten, molybdena, chromium, titanium, uranium, or manganese, with silver, are known.

Cobalt does not unite with silver unless with great difficulty. When these two metals are fused in a crucible, they remain separate from each other, the silver below and the cobalt above, by reason of their specific gravities. Gellert, however, observes, that after having fused two parts of cobalt and one part of silver, the latter, separated at the bottom of the crucible, had become more brittle and of a grey colour, while the cobalt was whiter than ordinary : it therefore appears, that some slight union takes place between these two metals, and that a division is effected between them.

Nickel does not unite at all with silver. When we fuse these two metals in a crucible, they remain distinct, and may be separated by the stroke of a hammer : sometimes they place themselves at the side of each other : though

their specific gravities are considerably different.

35. Bismuth unites very well with silver: there results a hard metal, brittle, lamellated, of a colour intermediate between that of bismuth and that of antimony, of a specific gravity greater than the mean resulting from that of the two metals: they adhere to each other so strongly that they cannot be separated without difficulty. When this alloy is exposed to a strong fire and the contact of the air, the bismuth is oxidated and vitrified, and at the same time in part sublimed, so that it may be employed like lead in the cupellation of silver, in order to carry off from it the metals which are more oxidable than itself. There are even cases in which the assayers prefer bismuth to lead, as it is oxided more quickly, and passes with greater facility into the cupel. Dufay proposed it in 1727, and Pott verified its use. The cupel is coloured yellow by this metallic matter; and it frequently cracks during the operation. Some chemists have asserted that bismuth cupelled alone left a small button of silver upon the cupel: but this latter metal is contained in it in such little abundance that it appears to be really of no consequence.

36. The alloy of antimony and silver is made very easily by fusion; there results a metal specifically heavier than the calculation of the weight of the two metals indicates, of little ductility, and of no use. Chemists have

long since remarked, that the sulphuret of antimony was decomposed by silver; that this metal united with the sulphur, whilst a part combined at the same time with the antimony. This last was formerly termed the *lunar regulus of antimony*.

37. Mercury has a great attraction for silver. In the experiments of Citizen Guyton, silver holds the second rank immediately after gold, with respect to its adhesion with this liquid metal. He has estimated it at 429, gold being 446, and tin 418; accordingly it unites with it very easily, and an amalgam is made, either by triturating leaves or fine filings of silver with mercury, or by adding heated mercury to red-hot silver in a crucible, or by precipitating silver from its solutions in the metallic form, and then presenting it to the contact of mercury. The consistence of the amalgam of silver varies according to the proportion of the two metals that are united. It is, in general, white, dull and soft; it is specifically heavier than the two metals which constitute it would indicate by their proper gravity; it even sinks to the bottom of running mercury. This property denotes a strong penetration between these two metals, and a reciprocal condensation; accordingly they become heated and dilated at first, at the moment of their combination. When we expose it to a gentle heat, continued for some time, it becomes ramified and developed into a kind of vegetation like the *tree of Diana*, of which

we shall speak hereafter. It has even been said, that when gold was added to it, the extremities of the branches of this tree bore small buttons of gold, which have been compared with the golden apples of the Garden of the Hesperides. If after having fused it, it be suffered to cool slowly, it crystallizes into lentiform leaves, or into square prisms terminated by tetrahedral pyramids. Though the action of the fire separates the mercury from it, as is seen in the treatment of some of the ores of silver, the last portions of this volatile metal are very difficult to be obtained, and it seems that the mercury is fixed a little by the silver. When left for a long time in the air, this amalgam hardens and becomes more consistent than it was before. It has been asserted, and it is not improbable, that the amalgam of silver, heated in contact with the air, in the apparatus in which mercury is heated in order to reduce it into oxide, undergoes together with it the same oxidation, and that this is a means discovered by the alchemists for oxidizing silver. This amalgama is much employed for silvering.

38. Silver unites easily with tin; but this alloy, instead of being useful, is considered as one of the most dangerous; and it is so much dreaded by the goldsmiths and artists who use or work silver, that they avoid even fusing tin and suffering its vapour to come in contact with silver, as it is supposed to deprive it of all its ductility. When we fuse these two metals to-

gether, we obtain a brittle mass, of a texture similar to that of the brittle metals, which flattens but very little under the hammer, on account of its hardness. When this alloy is exposed to a reverberatory fire, or under the muffle of the cupelling furnace, we obtain a vegetation, an oxidized scoria, which does not separate from the silver without much difficulty, though it be still soluble in mercury. It is extremely difficult, nay almost impossible, to purify this alloy by means of lead. Kraft and Muschenbroeck say, that tin increases the firmness or the hardness of silver. The latter asserts, that an alloy of four parts of silver and one of tin, is as hard as the combination of copper and tin; that a larger proportion of tin soon diminishes the firmness of the silver; that this alloy presents in its fracture a very fine granulated surface; finally, that a still more considerable proportion of tin renders the silver so hard that it is very difficult to file or even fuse it. It would be wrong to conclude from hence, that there is nothing good or useful to be hoped from this alloy of silver and tin, since its hardness, joined with its disposition to change, may render it valuable for several uses.

39. Lead combines very easily with silver by fusion; it even singularly favours the fusibility of the silver, as is proved by the phenomena of the cupellation. Kraft has found this alloy to be more dense, and specifically heavier than is indicated by the comparison of the specific gravities of

the two metals united. Muschenbroeck, who has carefully examined most of the metallic alloys, has likewise studied and treated of that of silver and lead. From his experiments he has drawn the inference, that the lead greatly diminishes the strength and firmness of the silver; and that the making of this alloy ought to be avoided in the arts. It approaches nearer to the colour of the lead than to that of the silver. Lead does not destroy the ductility of silver, like tin, but it deprives it of its sonorous property. Lead has more attraction for sulphur than silver has, and it decomposes with the aid of heat, the native or artificial sulphuret of silver. This alloy of silver and lead, is made only in order to submit the silver to cupellation: it is this which is obtained in the large way in the eliquation, as has already been said.

40. Iron easily forms an alloy with silver. According to Wallerius, an alloy of these two metals, in equal parts, has nearly the same colour as silver; it is harder, less flexible, though sufficiently ductile, and attractable by the magnet. Steel is folded with silver. Gellert observes, in his Table of the Affinities between the metallic substances, that silver has a stronger affinity with iron than with copper. It is singular that this kind of alloy has not yet been examined with much attention, as it seems to be calculated to become of great utility in the arts and in society, either by diminishing the price of certain utensils, or by communicating

to silver certain properties, which seem to be capable of adding to the utility and to the good qualities of this precious metal. Citizen Guyton; by fusing iron and silver, with his reducing flux, in Macquer's furnace, obtained two buttons, placed one at the side of the other, strongly foldered together, and sufficiently distinct, which seemed to indicate that these two metals are incapable of uniting.

41. Copper is one of the metals with which the silver alloys the best; and this alloy is one of the most useful. The principal advantage which it affords is, that it communicates to silver much more hardness than it naturally has; and that it consequently renders it much better adapted for making vessels, utensils, coins, &c. This alloy has several very remarkable properties. The density of the silver is diminished, though its firmness and hardness are increased; which indicates that the sum of the intervals between the particles of the alloyed mixture is greater than in each of the metals in particular, and that the additional hardness depends upon a different arrangement of the molecules of the silver, rather than upon their approximation, as we might have been led to believe, did not experience rectify our judgment in this particular. Citizen Haüy observes, that in the alloy authorized in commerce, in which the proportion of the silver to the copper is as 137 to 17, the specific gravity is 10,175; whereas, if there were no dilation of the metals alloyed, it would
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be 10,301; which gives about $\frac{1}{11}$ for the quantity of this dilation in the alloy here mentioned. A second very remarkable property of the alloy of silver and copper is, that the first preserves its white colour, though containing a considerable quantity of copper; so that this metal is enveloped in such a manner as not to become sensible, unless by chemical operations, more or less complicated. Newton, whose genius was struck by this singular property which exists in a more or less evident manner in most of the white metals, was led to conjecture, that the particles of the white metals had a more extensive surface than the yellow or red metals, that they were at the same time very opaque, and that they covered the copper without suffering the colour of this metal to shine through them. The alloy of silver with copper is determined in its proportions by strict laws, amongst all civilized nations, on account of the facility with which fraud may be committed by increasing the proportion of the copper, and in order to support the confidence of commerce. Wrought silver and silver coin have different standards in each nation: this standard in the French republic has a very essential advantage for the perfection of the arts, and of the calculations; namely, that it corresponds at present with the basis of the weights and measures, the original of which is taken in the measure of the earth, and which by this invariability grounded in the power and the laws of nature, have a pre-eminence over all
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the measures hitherto used, which will cause them sooner or later to be adopted by all enlightened nations.

G. Action of Water and of the Oxides.

42. THERE is no action between silver and water. To whatever temperature we may raise these two bodies, and however long we may heat them in contact with each other, they absolutely exert no attraction upon one another, and no change takes place in them; thus vessels of silver remain for a long time under water, without their properties or their nature being in any manner changed; only their colour is sometimes altered, either by the substances which the water may hold in solution, or by the deposition of those which are frequently suspended in it. This nullity of action between water and silver, depends entirely upon the little attraction that exists between this metal and oxygen; and as hydrogen so easily decomposes and reduces its oxides, it is very evident that it cannot take from this body the oxygen with which it is saturated.

43. It is for the same reason that it experiences no alteration from the metallic oxides, nor causes them to undergo any. On the contrary, its own oxide yields its oxygen to most of the other metals, and particularly to copper, iron, mercury, zinc, antimony, manganese, &c. There are some which divide with it only
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the greater part of its oxygen. Upon this double action of the metals on the oxide of silver depends the precipitation of this metal, either pure in the brilliant and metallic state, or in part oxidated, which is effected in its solution in the acids by means of the different metals that are immersed in it. We shall see hereafter that this is the cause of several remarkable phenomena, which have formerly been considered as a kind of chemical miracles, but which become very simple in their explanation according to the Theory which I have already set forth.

A. Action of the Acids.

44. THOUGH the little attraction which silver exerts upon oxygen renders this metal much less alterable and soluble by the acids than most of the metals which have hitherto been described; it is, however, infinitely distinguished from the two following, by the manner in which those burned bodies act upon it, and it is sensibly more alterable and soluble than they are.

The sulphuric acid does not attack it in the cold; but when we boil three or four parts of this concentrated acid upon one part of silver in clippings or filings, an effervescence ensues, with an abundant disengagement of sulphureous acid gas, and the metal is changed into a white mass or powder which dissolves entirely in water sharpened with a little sulphuric acid. Chemists

mists have compared this combination with that of mercury with the same acid, and there are, in fact, some points of resemblance between these two phenomena; but we never observe here that portion of insoluble oxide which the mercury presents. We obtain by the process here indicated a colourless solution of sulphate of silver with excess of acid, very sharp and caustic, which affords by evaporation small white and brilliant crystals in the form of very fine prisms or needles. If the solution be more concentrated, it sometimes deposits, in proportion as it cools (for much heat is produced whilst it takes place,) crystals in plates or laminæ sufficiently large, white, very brilliant, which have appeared to me to be formed by the union of compressed tetrahedral prisms.

45. The sulphate of silver is considerably fixed in the fire; it fuses and swells, and is decomposed by an intense heat, by which it blackens, yields sulphureous acid, oxygen gas, and is reduced into pure and ductile silver. Frequently, the vessels of glass in which this operation is performed become tinged with an olive-yellow colour. The light colours it, though slowly, brown or black. Phosphorus in a highly divided state, or burning sulphur reduce it without other heat; ignited charcoal decomposes it. The acids, excepting the muriatic which separates and carries down the oxide of silver, do not cause it to undergo any alteration. All the caustic alkalis and alkaline earths precipitate it into oxide of silver

Silver of a dark grey or brownish colour; especially by the contact of light; lime precipitates it in a greenish-grey powder; ammonia, after having precipitated and re-dissolved it; the muriatic, phosphoric, and fluoric salts precipitate it also by a double attraction; the carbonates form in it a white precipitate of insoluble carbonate of silver. All the precipitates of this salt formed by the alkaline substances are reduced in close vessels by means of heat, which disengages oxygen gas from them, and reduces the oxide to the state of pure silver. The alkaline sulphurets, and even water charged with sulphurated hydrogen, as well as sulphurated hydrogen gas, decompose the sulphate of silver, and form in its solution a black precipitate of sulphuret of silver; for the oxide is reduced by the hydrogen at the same time that the silver unites with the sulphur.

46. The sulphureous acid has no action upon silver; but its oxide easily combines with it. From the brown colour which it has, after having been separated from the nitric solution by a pure alkali; it assumes the form of small brilliant grains, of a pearly grey. This sulphite of silver is not changed in its colour and nature by the contact of the light. The sulphureous acid precipitates the nitric solution of this metal into a white powder of sulphite of silver. The same salt is obtained in the same form when the sulphite of ammonia is added to the nitrate of silver. An excess of this sulphite re-dissolves it and forms a triple salt.

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This sulphite of ammonia and silver, exposed to the sun, becomes covered with a pellicle of silver, and the liquor afterwards contains sulphate of ammonia. The sulphureous acid, aided by the attraction of the ammonia, carries off, therefore, the oxygen from the oxide of silver. When we mix oxide of silver with a solution of sulphite of ammonia, it dissolves in it, and forms the same triple salt equally decomposable by the action of the light. The muriate of ammonia decomposes the sulphite of silver, and the precipitate which is then formed is black and in part reduced, so that there remains sulphate of ammonia in the liquor. When exposed alone and pure to the light, the sulphite of silver becomes brown without being completely decomposed; heated by the blow-pipe upon a support of charcoal, it exhales sulphureous acid, is fused into a yellow mass, and leaves a button of pure silver; treated in a tube of glass passing through a furnace, it affords a little sulphureous acid, afterwards sulphuric acid, and leaves reduced silver as its residuum. The portion which is in contact with the glass, combines with it, and gives it a light brown or capuchin colour. Though very little soluble in water, it is rendered perceptible in it by the muriatic acid, which throws down a white cloud; it has an acrid and metallic taste. The caustic alkalis dissolve it and form with it a triple salt, analogous to the ammoniacal sulphate of silver which has been described. It

is evident, that there cannot exist any sulphurated sulphite of silver.

47. The nitric acid has always been considered as the true solvent of silver. And in fact, when we immerse into this acid, neither too much nor too little concentrated, silver in plates, in wires, or in filings, an effervescence quickly takes place. If the vessel be conical and very high, the nitrous gas which is disengaged from the bottom is dissolved in the acid, and tinges its inferior part with a green colour; it is evident, that this colour is not to be attributed to copper, since it disappears; as it does at the moment when the heat produced by the effect of the solution no longer permits the nitrous gas to remain dissolved in the liquid. If, on the contrary, the green colour is permanent and passes to a blue, if it augments in proportion as the solution advances, it is then to be concluded that it is owing to copper; of which we may convince ourselves by pouring into it a small quantity of ammonia, which greatly augments the intensity of the blue colour; but this does not happen with pure silver. When this metal contains a little gold, which occurs particularly in old pieces of silver plate, the gold not being sensibly soluble in the nitric acid in comparison with the silver, in proportion as the latter dissolves, a blackish or dark purple powder presents itself at the bottom of the liquor, which is nothing more than the gold beginning to be oxidated, as I shall show

49. The crystallized nitrate of silver, when exposed to the light of the sun, gradually blackens, and even changes at some points into small brilliant and metallic plates of a bright polish, which cannot fail to be recognized as pure silver. When heated in a crucible, it is quickly fused into a brown liquid, which swells, and becomes inflated as it loses its water of crystallization; and afterwards, in a gentle heat, it remains in tranquil fusion. If we suffer it to cool in this state of fusion, it concretes into a mass of a dark grey or blackish colour: by pouring it into an ingot mould of iron or copper, or rather into a mould formed of several small vertical cylindrical tubes, previously well greased or oiled, we obtain cylinders or pencils, blackish without, and presenting radiated needles in their fracture, which are employed in surgery under the barbarous name of *lapis infernalis*, on account of their causticity. In order to prepare this remedy, they do not give themselves the trouble in the laboratories of pharmacy to cause the nitric solution of silver to crystallize; but evaporate to dryness; after which they fuse the residuum in a capsule of silver, and pour it in the mould. The nitrate of silver must not be heated for too great a length of time when it is to be cast into *lapis infernalis*, which is only this salt deprived of its water of crystallization, and forming a coherent and solid mass; for if it be kept a little beyond its fusion upon the fire, and especially if the heat be inconsiderately augmented

it is decomposed and reduced into silver: globules of this metal are always found at the bottom. When we heat nitrate of silver in a retort with the pneumatic apparatus, we obtain nitrous gas, oxygen gas, very pure at first, afterwards mixed with azote gas, and the silver is found reduced into a pure and sufficiently ductile mass at the bottom of the crucible. I have several times, in this operation, seen the retorts and matrassee that were used, coloured of a very beautiful chestnut brown, and have attributed this effect to a small quantity of silver which had penetrated the fused or softened glass; for many other facts have shown me that the oxide of silver when pure and alone, is vitrified of an olive-green colour. When we place a plate of nitrate of silver, well dried upon an ignited coal, a detonation of considerable brilliancy takes place without the nitrate being fused or losing its form; it is a scintillation which traverses the whole surface of the salt; and when it is finished, we find upon the coal a layer of very white dull silver, which adheres to this body and assumes the bright polish or burnish peculiar to this metal when it is rubbed with a hard body, or even when we pass the nail over it. The solid layer of charcoal to which it adheres, becomes intirely and richly silvered by this simple process. Boerhaave called this reduction of nitrate of silver upon the ignited charcoal, *ardent silver*.

50. The nitrate of silver, which is pretty soluble in water, is reducible by hydrogen gas, and even by phosphorus in the liquid form. Thus in the experiments of Mrs. Fulhame, by exposing pieces of silk and paper, covered with nitric solution of silver, to the contact of hydrogen gas, a reduction of the metal took place, and the parts of these substances that were impregnated with the solution, became silvered. We here see the effect of the much stronger attraction of the hydrogen for oxygen, than that which silver has for this principle. More than fifteen years before the experiments of this English lady, the French chemists, Sage and Bullion, had discovered that when phosphorus was immersed in a solution of nitrate of silver, it gradually reduces the metal, and precipitates it upon the cylinder of phosphorus, forming a brilliant metallic tube, which intirely covers and envelopes it. This tube of silver may be separated from the phosphorus by plunging it into boiling water, which melts the phosphorus; and it has all the ductility, solidity, and tenacity of pure silver. There is therefore nothing new in the experiments of Mrs. Fulham, except the mere manner and the variety of the processes which she has put in practice, in order to present different combustible substances in a divided state to the metallic solutions. I shall return again to this subject in speaking of gold. Charcoal does not reduce the nitric solution

lution of silver in the same manner in the cold. It is probable that this reduction will hereafter be obtained by carbonated hydrogen gas. Sulphur does not effect it except when this solution is exposed to its vapour when it is burning, or especially to the contact of sulphurated hydrogen gas. In the latter case, there is produced, in the one instance, a black and pulverulent sulphuret of silver; in the other, a brilliant and metallic pellicle of silver. The same effect is produced by water which contains sulphurated hydrogen in solution, and by the contact of phosphorated hydrogen gas.

51. Several acids act in a very striking manner upon the solution of nitrate of silver; the sulphuric acid decomposes it, and precipitates from it sulphate of silver in a heavy and divided white powder. The sulphureous acid also forms in it a precipitate of sulphite which is blackened in the light. The muriatic acid, when poured into this solution, produces a white precipitate so abundant and so little soluble, that it is speedily deposited in heavy and thick flakes, which have long since been compared to *curd* or the *coagulum of cheese*; this is the muriate of silver of which I shall speak hereafter. The oxygenated-muriatic acid likewise precipitates the solution of nitrate of silver. The phosphoric acid also forms in it a phosphate of silver, white and insoluble; the fluoric acid produces a similar effect.

hands of a young man who rubbed its inside with his finger in order to clean it, and with the intention of making another experiment. In this effect we perceive the great tendency which the oxide of silver has to decompose the ammonia, the rapidity and the violence with which this decomposition takes place, and the small force or the slight change of equilibrium required for effecting this decomposition, since the slightest friction is sufficient to cause it to fulminate. In the dissolved part the oxide of silver appears to be at first too much oxygenated to produce the fulmination; but the action of the fire in the evaporation produces the disoxidation announced by the disengagement of azotic gas, and forms the fulminating oxide of silver which crystallizes, because insoluble in the water. The brilliant pellicle which covers the first ammoniacal solution, is owing to a portion of silver from which the air carries off the ammonia: it is necessary to dissolve it by ammonia, because its interposition greatly diminishes the fulminating property. The carbonate of ammonia dissolves the oxide of silver precipitated by lime with effervescence and disengagement of carbonic acid; but there remains enough of this acid to form a triple salt which leaves a yellow powder not fulminant by desiccation. A mixture of copper, or the absorption of the carbonic acid by the oxide of silver precipitated by means of lime and left for too great length of time in the air, or ammonia containing a little of this acid,

acid, either diminish or destroy this fulminating property of the precipitate: so that we may fail in this preparation, either because we have taken silver alloyed with copper, or because we have not sufficiently separated the nitrate of lime which impregnates the first precipitate, or because we have used ammonia that contained carbonic acid, or lastly, because we have suffered the precipitate to absorb this acid from the atmosphere: such are the reasons why this delicate operation is seldom performed with success. I recollect upon this occasion, that having observed in 1780, the non-precipitation of the nitrate of silver by ammonia, and intending to examine its cause, I collected from that time, every year, the mixtures of nitrate of silver and ammonia, and purposed to study their properties, when Citizen Berthollet published his discovery at the end of the year 1787. It had belonged to my plan to evaporate this liquor: and I should infallibly have obtained a very violent and a very dangerous fulmination, if the experiments of Citizen Berthollet had not apprised me of the imminent danger which I was preparing for myself without being aware of it. To judge from the violent effects of the small quantity which I have heard, and even seen detonate, the large mass of fulminating silver which I had prepared and collected from year to year, would have occasioned a terrible detonation which might have been accompanied with great danger. This oxide must not be
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confounded on account of its fulminating property, with other precipitates of silver equally fulminating, but which have no relation with it. The detonation by friction proceeds from the same cause as that which produces a very violent inflammation and oxidation in the percussion of super-oxygenated muriate of pot-ash with combustible matters upon a hard body. We recognize in it a sudden approximation of the particles which, at a small distance, react upon each other. The precipitates of nitrate of silver, by the fixed alkalis, when treated with ammonia, furnish precipitates having but little detonating power in comparison with that which lime-water affords.

54. Many salts possess the property of acting upon the nitrate of silver. All the sulphates render its solutions turbid, and precipitate sulphate of silver in powder; the sulphites produce upon it a similar effect; the muriates not only form in it a deposit, heavy and thick like a curd, but are in every case distinguishable by the aspect presented by their solutions with the nitrate of silver. The soluble phosphate, the fluates and the borates comport themselves nearly in the same manner. The carbonates, as I have already announced, separate from it a white and insoluble carbonate of silver.

55. Most of the metallic substances having more attraction for oxygen than silver has, precipitate it from its nitric solution some less oxidated than it was before, others entirely deprived

prived of oxygen, and in its brilliant and metallic form. Amongst these precipitations there are especially two which deserve the most serious attention of chemists; the one, because it presents a very interesting phenomenon; the other, because it is practised upon a large scale in some arts in which it is employed with great advantage. The first gives rise to what is called the *Tree of Diana*; this is a separation of the silver in the state of amalgam, and in a needled crystalline form, which resembles the figure of a shrub. Lemery directed, in order to obtain it, to dissolve one part of silver in moderately strong nitric acid, to dilute the solution with twenty parts of distilled water, and to add to it two parts of running mercury. It required about forty days to obtain a very fine metallic vegetation. Homberg afterwards described a process which is shorter, and which succeeds well: it consists in making an amalgam in the cold, with four parts of silver in leaves, and two parts of mercury, dissolving this amalgam in a sufficient quantity of nitric acid, and diluting the solution with water to the amount of thirty-two times the weight of the metals. A small ball of soft amalgam of silver is put into this liquor, and the tree of Diana is immediately formed. This precipitation is also very quickly effected by putting a soft amalgam of silver into a mixture of six parts of nitric solution of silver, and four parts of nitric solution of mercury. In these two latter processes, one part of the mercury of the amalgam, being attracted by that of the
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the solution, takes the oxygen from the silver, and precipitates it in the state of metal; and the precipitation of the latter is also favoured by the attraction exerted upon it by the undissolved portion of mercury, as well as by the portion of silver of the amalgam. All these attractions which act simultaneously, quickly effect the separation of the silver, which is deposited as it becomes amalgamated; and this amalgam is deposited in aculeated prisms, which arrange themselves one upon the other in the form of ramifications. In order to render it the more beautiful, a conical vessel is chosen, and care is taken to prevent any shock which would oppose the symmetrical and regular arrangement of the amalgam, and prevent the formation of the tree.

56. The precipitation of metallic silver by copper is of a very different importance from the preceding; it is one of those that are practised most frequently in mints and the workshops of silversmiths. At the moment when we plunge clean and well-brightened copper into the nitric solution of silver, the plate becomes brownish, covered with small metallic crystals, of a dull white colour, which soon increase, arrange themselves about the plate, and envelop it like an efflorescence, which adheres neither to the copper nor to each other; they are detached by the slightest concussion, and especially by gently lifting out the plate of copper charged with this silver, which contracts and seems to be condensed

denfied, when it is taken out of the folution, and agitated in pure water. It is in this manner that they feparate in the mints the filver diffolved by the operation of parting; plates of copper are dipped in the folution, or this laft is put into a veffel of copper; the filver feparates into flakes of a whitifh-grey colour; the liquor is decanted when it has become blue, and yields no more filver: the latter is wafhed with feveral waters, then flightly ignited in a crucible, and fold under the improper name of *filver in calx*, becaufe it is in white and dull grains; it contains a little copper. It is alfo fufed in crucibles; it is paffed with lead into the cupel, in order to feparate from it the portion of copper which it contains; and then becomes the pureft filver of commerce, and it is called *fine filver*, or filver of twelve deniers. Sometimes the fame precipitation of filver is employed for applying this metal upon copper in a kind of filvering; but it contracts too little adhefion for this kind of filvering to be durable, on which account the application of the filver to the copper with the amalgam is preferred: this is what is called water-gilding in the art of the gilder and filverer.

57. The muriatic acid, in whatever ftate of concentration it may be, gafeous, vaporous or liquid, does not act upon filver, and never effects its oxidation. This effect has been erroneoufly believed to be produced in what has been termed the dry parting; it is not merely muriatic acid that is difengaged in this operation, but

but real oxygenated muriatic acid. By cementing plates of gold, alloyed with silver, with a mixture of sulphate of iron and muriate of soda in a crucible, the sulphuric acid, disengaged from the sulphate of iron, by the action of the fire, seizes upon the oxide of iron, takes from it a portion of its oxygen, and afterwards acts upon the silver, to which it yields this principle; so that after having oxidated it, the other acid unites with it as the ordinary muriatic acid does with the oxide of this metal. Though the muriatic acid cannot act upon metallic silver, at least unless it be oxygenated, because it has more attraction for the oxide of silver than most of the other acids have, and especially than the sulphuric and nitric, yet as soon as it is placed in contact with these solutions of silver, it decomposes them; it takes from them the oxide of silver, and forms with it an insoluble white salt, which is precipitated in a kind of curd, as I have announced upon a former occasion. I have likewise shown that the muriates act in the same manner as the muriatic acid alone, and that they form, in the nitric and sulphuric solutions of silver, a precipitate similar to that which is formed by the pure acid. It is even on account of this easy and quick precipitation, that the nitrate of silver is a very sensible re-agent for indicating and ascertaining in the mineral waters, and in all liquids, the presence and the quantity of the muriates, or of the muriatic acid dissolved in them. Bergman has shown, that the Swedish kanne, or two quarts and three quarters of water, holding

holding a single grain of muriate of soda in solution, exhibited very sensible streaks upon the first drops of nitrate of silver that were poured into it: thus this metallic salt indicates the presence of about $\frac{1}{100000}$ of muriatic acid contained in liquids; there is hardly an instance of an equal sensibility among the re-agents.

58. The muriate of silver, produced by the decomposition of the nitrate by the muriatic acid, or the different muriates, is in the state of a powder or a thick white magma; in the light it becomes brown, dark violet, and black; it is one of the compounds that are changed the most rapidly by the contact of the solar rays. However, this change takes place only at the surface, and the interior part remains white; it is also one of the most fusible salts that are known. When gently heated in a matras, or a small phial, it melts like fat, and afterwards becomes fixed, by cooling, into a semi-transparent grey substance, considerably resembling some kinds of horn, on which account it was formerly termed, in this state, *luna cornua*. If it be poured upon a stone, it fixes into a friable matter, crystallized in fine brilliant, and as it were metallic needles; when heated more strongly in a crucible, it becomes extremely fluid, and filtrates as if through a net or canvass, and is lost in the fire. In this case a small quantity of silver is always reduced and disseminated in globules, in the portion of fused muriate, which still remains; it

is

is not soluble, unless in more than a thousand times its weight of boiling water. Monnet has affirmed, that a pound of water could take up by ebullition only three or four grains of it. The alkaline carbonates decompose this salt, and precipitate an oxide of silver from its solution; but this action is so feeble that the precipitation is very little observable, and the process can serve for no use. It is, however, of very essential consequence for all the arts in which silver is operated upon, to have a sure means for extracting this metal from its muriate, as it is frequently obtained under the form of this salt, on account of the different operations to which it is subjected. Besides, in chemistry, silver extracted from the muriate is always employed as the purest that can be obtained: it was formerly called *silver revived, from luna cornea*; and accordingly the chemists have sought the means of reducing the muriate of silver. The process most generally employed, and which has become, on account of its facility and success, the familiar process in the refining workshops, consists in mixing four parts of pot-ash of commerce, or rather of carbonate of pot-ash, with one part of muriate of silver; placing the mixture, and rapidly fusing it in a good crucible; when it is in complete fusion, the crucible is taken from the fire, and suffered to cool slowly; then broken, and the silver is found in a button under the fused muriate of pot-ash and alkali which cover it. When the fusion is per-
formed

formed with rapidity, the whole of the muriate of silver is well decomposed ; none of it is lost through the sides of the crucible, and the silver is very pure at the bottom of the vessel. It is necessary to take care of the swelling produced by the disengagement of the carbonic gas, effected by the muriatic acid. The crucible ought to be sufficiently large to guard against the running over of any part of the matter. Bergman estimates the muriate of silver to contain 0,75 of oxide of silver, and 0,25 of muriatic acid.

59. It had been believed, and in fact it was natural to believe, according to the order of the attractions the most generally known between the acids and the metallic oxides, that pure pot-ash and soda decompose the muriate of silver : but Citizen Vauquelin has found in this salt a very remarkable exception, which appears also to take place to a certain degree with the oxides of mercury and of lead. Having heated muriate of silver with a caustic ley of soda, and having perceived that this alkali had not taken up a single atom of muriatic acid, he threw oxide of silver recently precipitated from the nitrate of this metal into a solution of muriate of soda ; this precipitate, whilst still wet, suddenly lost its brown colour, became white, and collected into thick flakes, or a curdled magma ; the saline taste of the solution was changed into an acrid, alkaline, and caustic taste. The supernatant liquor being
evaporated

evaporated, after the separation of the precipitate, which was real muriate of silver, yielded crystals of carbonate of soda without admixture of marine salt. It results from this experiment, not only that the muriatic acid has more attraction for the oxide of silver than for soda, but also that this oxide has the greatest possible attraction for the muriatic acid, since the oxides of all the other metals are separated and precipitated from them by the alkalis. The same chemist has found that it was necessary to employ much oxide of silver in order to decompose the muriate of soda.

60. The muriate of silver is very soluble in caustic and liquid ammonia. This solution, which is very clear and colourless, experiences a remarkable change when it is left exposed to the air. In proportion as the ammonia exhales from it into the atmosphere, there is formed at its surface a pellicle which assumes a very brilliant blueish or rain-bow colour: this pellicle, which augments gradually in thickness, becomes darker at the same time, and at last acquires a dirty grey and blackish colour by the contact of the light. The matter which is thus separated at the surface of the liquor, is easily recognized to be real muriate of silver, containing a little reduced metal. Ammonia, is constantly found to produce the same effect of solution and reduction, more or less complete upon all the salts and precipitates of silver, as I
have

have already indicated in the history of the nitrate of this metal.

61. Margraff, towards the middle of the eighteenth century gave a particular process for decomposing the muriate of silver in the humid way; it is founded upon an exact knowledge and application of the double elective attractions; but it is too expensive and troublesome to be employed even in the large way. He advises to treat in a mortar of marble or glass, one part of muriate of silver with three parts of concrete volatile alkali, or carbonate of ammonia: to this mixture was added a sufficient quantity of water to form it into a paste; it was stirred till the effervescence and swelling produced by the disengagement of the carbonic acid had subsided; six parts of running mercury was poured into it, and it was triturated till a fine amalgam of silver was produced; this was washed and continually triturated till the water passed off clear, and the amalgam became very brilliant at the bottom of the mortar. It was then requisite to dry this amalgam, and distil it in a retort of stone-ware, till the vessel was heated to ignition: the mercury passed into the receiver, and the silver remained pure and nearly without diminution, at the bottom of the retort. In this operation, the water carried off muriate of ammonia in solution, and a white powder, which was nothing more than mild muriate of mercury, carrying with it a little silver in a dull powder: by subliming this mu-

riate of mercury its nature was ascertained. It is evident that, in this process, whilst the ammonia combines with the muriatic acid, the mercury takes from the highly-divided oxide of silver its oxygen, and reduces it to the metallic state, precisely in the same manner as in the preparation of the Tree of Diana; that this silver is strongly attracted by the portion of mercury which is superabundant to its disoxidation. I have here quoted and described this process only in order to prove that the muriate of silver, like the nitrate of this metal, is susceptible of being decomposed and reduced in the cold by mercury.

62. Many other metals, especially bismuth, antimony, zinc, tin, lead, iron, and copper, are also capable, and by the same principle, of decomposing the muriate of silver. Their use in chemistry has sometimes been recommended for obtaining the silver from this salt. It is directed in books to fuse one part of muriate of silver with three parts of these metals; after the fusion, the silver is found melted into a button at the bottom of the crucible, and the metal employed remains at the surface united with the muriatic acid. But as more of these metals is taken than is required for saturating the muriatic acid, a part combines with the silver, which is thus obtained only alloyed, and requires to be refined by means of lead and the cupel, so that it is not more pure after this operation than by the ordinary processes.

63. The phosphoric acid unites with oxidized silver, and precipitates it from its nitric solution. The precipitate thus obtained is white, heavy, and thick; it is fused by a strong fire into a kind of greenish or olive-coloured enamel, accordingly as it has been more or less heated. This phosphate of silver is not soluble in water, but it is in an excess of phosphoric acid. When treated in a crucible with charcoal, it affords a little phosphorus, and a great part of it is reduced into phosphuret of silver, which contains from 0,15 to 0,20 of phosphorus. However little the phosphoric acid, extracted from bones in the ordinary manner, contains of sulphuric acid, which happens almost always, I have perceived that by evaporating it in vessels of silver, they were corroded and penetrated when the liquor was well concentrated; the oxide of silver formed by the sulphuric acid, is taken up by the phosphoric acid; so that by fusing this last in a crucible, we obtain, instead of a transparent glass, a greenish-grey enamel, part of which is phosphuret of silver.

64. The fluoric acid does not appear to attack metallic silver; it unites well with its oxide, and forms with it an insoluble salt, which the other acids decompose, and from which they expel the fluoric acid. The other properties of this salt have not been examined; it has been erroneously confounded with the muriate of silver, and this has caused it to be be-

lieved, from the fluoric acid precipitating the nitrate of silver in a white and heavy powder, that this acid was the same as the muriatic.

65. The boracic acid does not act at all upon silver. It is combined with the oxide of this metal by pouring upon its nitric solution a solution of any soluble borate. The borate of silver is precipitated in a white, very heavy, and insoluble powder. The properties of this salt have not yet been examined.

66. The carbonic acid has no action upon silver, but it unites easily with its oxide. This even when it is moist, absorbs carbonic acid from the atmosphere, and it is frequently in consequence of this absorption that we fail in the preparation of the fulminating ammoniacal oxide of silver, as I have already indicated. When the fulphate or the nitrate of silver is precipitated by the alkaline carbonates, we obtain carbonate of silver in insoluble white powder. This salt, which is rendered black by the contact of light, easily yields its carbonic acid by the action of fire; and after having given out pure oxygen gas, which hardly amounts to more than 0,11 or 0,12, to 100 parts of the most complete oxide of silver, it passes into the state of ductile silver.

67. Scheele has described the manner in which the arsenic acid acts along with silver by digestion, that is to say, by heating this acid, dissolved in water, upon silver, the latter is not attacked by it; but when the water is evaporated

evaporated, and the action of the fire is continued till the acid is vitrified, arsenious acid is sublimed, and there remains a white vitreous mass which contains oxidated silver, and is covered with a glass of a deep yellow colour. By heating water upon these two kinds of glass pulverized, they become of a brown-red colour; the arsenic acid being dissolved, carries away a small quantity of oxide of silver which the muriatic acid shows in it, and precipitates from it. The brown powder, which does not dissolve, is fused by a strong fire, and assumes a semi-transparency; by continuing the fire in a crucible, the silver contained in it is reduced. The nitrate of silver is precipitated in a brown state by the arsenic acid, as well as by the arseniates. The muriatic acid decomposes this precipitate, and takes from it the silver, which it separates from the arsenic acid. Ammonia also dissolves this arseniate of silver: it is on account of the red colour of the arseniate of silver thus obtained by precipitation, that chemists have imagined they had the red silver ore, whereas that, as I have already shown, is a sulphurated oxide of silver and of antimony. Scheele has also found that the liquid arsenic acid, mixed with muriatic acid, and digested upon silver in fine filings, oxidated it, and favoured its combination into muriate of silver. The arsenic acid at the same time assumes the state of arsenious acid.

68. The tungstic acid does not appear to have any action upon silver; but it carries off its oxide from the nitrate of this metal which it precipitates in a white powder. The properties of this tungstate of silver have not yet been examined; the same is the case with the molybdic acid. Its union with silver is not yet known; it appears to precipitate the nitrate of silver, as the tungstic acid does, and to form with the oxide of this metal a white, pulverulent, insoluble salt.

69. The chromic acid, united with the oxide of silver, forms a very remarkable combination. When chromate of pot-ash is poured into the nitric solution of silver, there is produced a pulverulent precipitate of the most beautiful carmine red, which becomes purple by being exposed to the light. The chromate of silver, heated by the blow-pipe, is fused before the coal, which supports it, inflames; it assumes a blackish and metallic aspect. When pulverized in this state, it is still purple; but as soon as it is heated with the blue flame of the candle directed by the blow-pipe, the salt assumes a green colour, and the silver separates from it into globules disseminated in the mass. The chromic acid, decomposed by the hydrogen of the blue flame, passes again into the state of green oxide, and the oxide of silver is reduced. It may be foreseen that the purple chromate of silver may at some future time be discovered
amongst

amongst the ores of this metal. It exists in nature.

I. Action on the Bases and on the Salts.

70. SILVER forms no combination with the earths. When it is in the state of oxide it is capable of uniting by vitrification with some of them, and colouring the glasses or the enamels with yellowish, olive-green, and brownish shades; accordingly it is for the purpose of obtaining some of these varied tinges that it is employed; but it is not of much value in this kind of painting.

71. The caustic, or pure alkalis, do not produce any alteration upon silver. Its oxide is soluble only in ammonia; and if we expose this solution for a long time to the light, the ammonia is decomposed, azote gas is disengaged, water is formed, and the silver is reduced. We have already seen that in some cases this reduction is accompanied with a violent detonation or fulmination, which may even be determined by contact, or the slightest friction, or at least by pressure when the substance is not dry.

72. No salt, properly so called, has any action upon silver. This metal comes pure and without alteration from the trials to which we may expose it with the different saline substances. It is not sensibly oxidized either by the nitrates or the super-oxygenated muriates. The oxidable metals, on the contrary, which it so frequently

frequently contains are attacked and gradually burned by these substances; and I have remarked upon a former occasion that nitre is one of the means for purifying or refining it. It has, moreover, too little attraction for oxygen to be susceptible of alteration by the metallic solutions. However, its oxide has more attraction, as we have seen, for the muriatic acid than pot-ash or soda has.

K. *Uses.*

73. THE uses of silver are so generally known, that it is superfluous to enter into many details concerning them. It is employed by all civilized nations for representing all the productions of nature and of art; it is alloyed with a determinate quantity of copper; it is struck into numerous and portable medals, which are called *money*, and which, with a constant standard and weight, form amongst men united into organized political societies, the price of all kinds of merchandize and provisions. In this point of view it is the type of wealth and ease; but it is less its real quantity, than its prompt and rapid circulation that constitutes the prosperity of nations. Its particular value is founded upon its scarcity or its abundance, as its quantity is always augmented by that which is extracted from the bowels of the earth: its uses and employment are numerous; so that it has gradually come into use in applications and uten-

sils

filis for which it had not at first been destined: hitherto this augmentation has been perceptible from one generation to another, from century to century, not only by the multiplication of the objects fabricated with silver, but also by the increased cheapness of the coins of this metal, compared with the different merchandises or productions which they represent.

74. The use of silver for utensils, and especially for those which are subservient to the necessities of life, for preparing and taking our nourishment, is the most essential of all; in this point of view, it is really one of the most precious of metals, on account of its beautiful properties, its unchangeableness, its inoxidability, and its insolubility in a multitude of substances. It were even to be wished that it might be appropriated more frequently, more generally, and especially more abundantly to the service of the interior of our houses than has hitherto been done, and that it might be considered rather as an object of salubrity than as an article of luxury. In this respect the services which silver may afford to mankind might even be multiplied, by carrying much further than has hitherto been done, the art of applying it to copper, or of making with thin plates of this metal, folded by heat and pressure to thick plates of copper, the article called *plated silver*. The members of the Academy of Sciences have ascertained, in 1788, that a plate of pure silver extremely thin, applied

plied accurately upon copper, defended it entirely from the contact and the action of all substances, and that with at most a thirtieth of the weight of the copper in silver plated upon this metal, very useful kitchen-utensils might be made, far preferable to the ordinary tinned copper, both with respect to the reliance that could be placed upon them, and their duration.

75. However, notwithstanding the wise advice of these able and philanthropic men, we yet scarcely ever see these vessels with surfaces of silver, these so advantageously plated utensils, in use. Silver is reserved only for the arts and the objects of ornaments; it is not in the kitchens of the opulent, it is not in the preparation of their food that it is employed; it is consecrated to luxury, show and ornament. The art of rendering it subservient to this pleasure of the eyes, has been carried very far in France; and artists, by an industry no less admirable than useful, multiply its real value in a thousand ways. Associated with design, this art gives it the purest and most beautiful forms. The most lively brilliancy of polish or burnish, contrasted with the dull parts of a pure white colour, forms one of the most beautiful and pleasing objects which the eye can behold. Beaten into thin leaves, drawn into attenuated wires, mixed with silk and wool, applied to the surface of wood, of other metals, and of a multitude of bodies, it adorns our habitations,

our domestic furniture, and our apparel ; in the form of silvering it defends most of the substances which it covers from an alteration which they would experience without this integument of silver. Besides enriching them with its beautiful colour, and clothing them in its splendid dress, silver also removes or annihilates their disagreeable or dangerous properties.

76. Medicine has in vain sought in silver for virtues capable of palliating or curing diseases ; it has only afforded, when taken in combination with the acids and oxygenated, a violent caustic which is employed merely for some external applications, and ought never to be used internally, though the nitrate of silver modified in different ways, has been recommended under the names of *argentine hydragogue* of Boyle and Angelus Sala, of *lunar tinctures*, of *lunar bezoar*, of *lunar pills*. It has in vain been attempted to attribute to it a fortifying and alexipharmic quality. A more rigorous observation has demonstrated that it is intirely and absolutely inert in its metallic state. It is at present even rejected from those electuaries to which it was added in order to render them pleasing to the eyes of the patients by their shining appearance. It is now confined to the humble use of covering pills, of which it conceals the colour and diminishes the disagreeable properties.

ARTICLE XXI.

*Of Gold.**A. History.*

1. GOLD is in the same predicament with silver. The period of its discovery loses itself in the obscurity of antiquity, and no tradition amongst mankind affords any trace of the events by which they were first made acquainted with it. It cannot be doubted that its fine properties, its unalterability, its indestructibility have been highly valued almost as soon as it was discovered, and that they soon became the object of general esteem and almost adoration. Accordingly the folly which has for its chimerical object to form it in a direct way, to create it as done by nature, is one of the maladies under which the human race has long laboured. Whilst some fanatics have exhausted themselves in ruinous endeavours to produce gold, the multitude has generally been carried away by the desire of acquiring and accumulating it. The philosopher who calculates the crimes of all kinds which this ungovernable passion has caused to be committed upon the globe, is obliged to conclude, that, notwithstanding the advantages which this metal has
procured

procured to society, the sum of the evils which it has produced greatly exceeds that of the good which has been derived from it.

2. In the series of the numerous researches and experiments that have been made upon gold, the long and arduous labours undertaken by the alchemists hold the first rank, and open, as it were, the scene of the chemical discoveries, of which it has been the object. After having considered gold as the most pure, the most perfect, the most unalterable, the most simple of metals; after having decorated it with the vain title of king, they have compared it to the sun, and have represented it by the same emblem. A circle was the symbol of its perfection and its immutability; it was with them the extreme, the *summum* of metallization, the most perfect work amongst the fossils; and in their delirium they had almost placed it at the head of the creation. Not only, according to them, it contained nothing acrid, nothing foreign to the metallic nature, but it was the product of an accomplished maturation, of a perfected incubation. Hence the slow experiments to which they subjected the other metals, in order to mature and perfect them; hence the indefatigable patience with which they conducted their researches, and even the ridiculous forms which they gave their instruments. Silver, as the nearest to the state of gold, required, in their hypothetical opinions, to undergo only a last degree of amelioration to afford a tincture,

to

to experience a sort of refinement, and fixation.

3. Unhappy operators in an art that has never existed, and of which it is doubtful whether the object will ever be determined, though we cannot be certain that it is absolutely impossible to discover its nature and intimate composition,—the more the alchemists have laboured, the more they seem to have wandered from the object they wished to attain. Every fact has hitherto proved that gold, like the other metals, is an indestructible body from which we cannot separate any principle, which we cannot in any manner decompose, and which acts in all the circumstances of chemical operation as a simple or indecomposable matter. Whilst they accomplished nothing that they wished to accomplish, the alchemists have taught us how to treat gold in many different ways, to change its form and properties, to restore it to its first state, to obtain it equally pure, equally brilliant, and equally unaltered from the multiplied tortures to which they subjected it; to cause it to enter into different compositions, and especially to render it subservient to several curious and useful operations.

4. It was from the pompous accounts of the alchemists that the first systematic chemists derived the truths which they began to collect and arrange methodically concerning gold. They have equally profited by the numerous labours

labours of the adepts undertaken in the intention, always fallacious and ever revived till the dawn of experimental physics, of finding in this metal a panacea, an universal remedy. All the formulæ of potable gold, of aurific tinctures and elixirs, all the pretended means for dividing, attenuating, dissolving it, have been received by the true chemists as so many facts concerning its affinities and combinations. The more rational labours of assayers and metallurgists upon the art of assaying, purifying, extracting, refining, alloying, fusing, casting, working, and employing gold in a thousand different ways, have furnished many useful details to chemists for composing of the history of this important metal. Lastly, the numerous and industrious practices of several arts in which gold is employed in order to give it an hundred different forms, to multiply its surfaces, to communicate its brilliancy to trinkets, have also served to instruct the authors of the treatises of chemistry, and from this prolific source have been derived all the facts which compose its particular history.

5. Of all metals gold is that which has had the greatest number of particular historians or monographic authors. Though most of the works of alchemy have only presented its fabulous history, we may, however, rank them in this class of monographic treatises on gold. Amongst those which have afforded the most useful or singular facts, and which, without being intirely free from
from

from alchemical ideas, have given them at least with some rationality, we must particularly distinguish Glauber, Clavius, Dickinson, Helvetius, Orschall, Kunckel, Barba, Borrichius, Cassius, and Henckel. Boyle, Muschenbroeck, Nollet, amongst the natural Philosophers, have collected the most useful facts concerning the physical properties of gold. Wallerius, Lewis, Eschembach, Gellert, Salchow, Tellet, Born, Ferber, Sage, Ribaucourt, are the chemists who have written best upon the assaying, or the treatment in the large way, and the totality of the properties of this precious metal. Bergman and Scheele, Citizens Van Marum and Berthollet, have in the last place added some important facts relative to the oxidation, the solution, and to several of the compounds which gold is capable of forming.

6. Though since the rise and establishment of the pneumatic doctrine particular and consecutive researches concerning gold have not been made, this doctrine has greatly advanced our knowledge of the properties of this precious metal. To this doctrine is to be attributed the precise notion of the oxidability of gold which was not comprehended before, of its solubility in some acids, and of its insolubility in others; of the different phenomena of its precipitations; of the salts which it forms; of its little attraction for oxygen, compared with that of the other metals for this principle; in a word, of all the properties which distinguish and charac-

erize

terize it, as the details upon which I am about to enter will prove.

B. *Physical Properties.*

7. GOLD is one of the most brilliant and most beautiful of metals; its particular yellow colour and its remarkable lustre attract and delight the eye, though, they are, perhaps, less lively and less agreeable than in silver. Malouin remarked, that in the lectures which he delivered upon gold, the appearance of his hearers exhibited signs of joy and satisfaction when he presented this metal to their sight; and it is certain, according to familiar and frequent experience, that a large surface of well burnished gold attracts the eyes of all, and excites in those who view it a sentiment of hilarity, a kind of pleasure of which it is very difficult not to seize the impression when we attentively observe those who experience it. It cannot be doubted, that this sentiment is natural, and indicates a real enjoyment. Undoubtedly, the moral faculties of individuals, affected by the value which they attach to gold, contributes to it; but this property of the colour of gold is not the less certain, though we are not authorized to conclude from thence, that this metal has an alexiteric and alexipharmic quality, as was done sixty years ago in medicine. The colour of gold is not constant in its tinge or shade; a great number of circumstances may cause it to

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vary: we may distinguish the whitish-yellow, the pale, and as it were lemon-yellow, the greenish-yellow, and the reddish-yellow colours; but it is probable that this difference, which is too considerable to be owing to different physical conditions, proceeds from some metals which are alloyed with it. Newton having found that a very thin leaf of gold, placed between the eye and the light, appeared of a greenish blue colour, concluded that this metal, while reflecting the yellow rays, admitted by refraction in its interior a little blue light, which, after having been reflected in different directions by the metallic particles, was entirely extinguished.

8. The density of gold is such that it has long been believed to be the heaviest body in nature; but it is now known that it holds only the second rank, and that it yields the first place to platina. Cronstedt and Wallerius have indicated the proportion of its weight to that of water as 19,640 to 1,000. Lewis estimated it between 19,300 and 19,400; Muschenbroeck found it 19,640, 19,521, 19,238; it is most commonly reckoned at 19,258: the wrought is a little heavier than the cast. Its hardness is not very considerable; according to Citizen Guyton, it holds only the fifth rank amongst the metals; it is so soft that it may be bended in all directions, and it is indispensably necessary to harden it by an alloy in order to make use of it; its elasticity is feeble as well

as its sonorous property, which is frequently designated by the epithet of obscure.

9. The ductility of gold is one of its most singular properties, and which excites the most admiration when compared with that of other metals, and when acknowledging its superiority we consider the phenomena to which it gives rise. According to very well made calculations by Wallerius, Reaumur, Lewis, Geoffroy, &c. a grain of gold may be drawn into a wire 500 feet in length. Boerhaave even mentions, after Cassius, a workman of Augsburg, whose dexterity was such that he actually drew a grain of gold into a wire of 500 feet. An ounce of gold may gild a silver wire 444 leagues in length; a grain of gold flattened into leaves may cover an area of more than 1400 square inches. It may be lengthened or beaten out in such a manner as to occupy 65,590 times the space which it formerly did. Its tenacity is also the most considerable that is known. A gold wire one tenth of an inch in diameter supports a weight of 500 pounds before it breaks. Reaumur observes, that a layer or a leaf of gold covering silver wire of $\frac{1}{1000000}$ of an inch forms a continued opaque tube, which, according to an experiment of Haller, may be obtained entire and separate from the silver, by dissolving the latter in nitric acid. This astonishing ductility of gold gives place to a stronger hardness and elasticity when the gold has been beaten, compressed, passed through the wire-

drawing plate. It is then said, that the gold is hammer-hardened, but its accustomed ductility may be restored to it by heating it to redness and cooling it gradually.

10. Gold is a good conductor of caloric. Neither this property has been accurately determined nor its dilatability by the action of the fire, though it is known in general, that it is nearly proportionate to its fusibility. Gold becomes red when it is penetrated with a sufficient quantity of caloric; and afterwards when it is of a lively green, it softens, fuses and runs. The fusion of pure gold is pretty easy. Mortimer estimated it at 1300 degrees of Fahrenheit's Thermometer. Citizen Guyton has determined it at 32 degrees of Wedgwood's pyrometer, whilst, as I have already mentioned, he determines that of silver at 28. It is observed in the workshops of the goldsmiths, that gold in filings or in small spots, fuses with greater difficulty than the gold in ingots or in larger pieces, or that it is difficult for the small fragments to form one single piece by their fusion, and that they often remain like those of the silver in separate globules. Accordingly, in order to make them unite into a single homogeneous mass, which they call collecting the gold, they throw into the crucible a little nitre or borax, which appears to destroy the small foreign bodies, the powders with which the small fragments of gold and silver were surrounded, and which prevented them from uniting.

ing. Another practical observation of no less importance, respecting the fusion of gold, is that if the simple degree of heat necessary for its fusion were only given it, it would remain brittle after having cooled: one is obliged to raise it to a much higher temperature than that which is sufficient for its fusion in order to preserve its ductility. The same inconvenience takes place when it is suffered to cool too suddenly, when it is poured into a cold ingot-mould: these utensils must, therefore, be well heated before the fused gold is poured into them.

11. By augmenting the heat of the fused gold, it seems to assume a more convex form at its surface, whereas it flattens when it becomes fixed. Lewis attributes to this effect the want of exactness in the form which pure gold assumes in the moulds. If we suffer it to cool slowly, and if at the moment when it becomes fixed at its surface, we break the solid crust and pour off the liquid portion which it covers, it affects, in the cavity left by this decanted portion, a crystalline and regular form, which has been obtained and well described by Mongez and Tillet: it consists of very distinct quadrangular pyramids, or regular octahedrons. It presents the same form in Nature. By continuing to heat it when in perfect fusion we see it agitated, turning as it were upon itself and assuming a kind of motion of ebullition. This phenomenon, which was well observed under the focus of the burning glass of the Academy by Homberg and

Macquer, and which we may see whenever we fuse a small globule before the blow-pipe, terminates in a real volatilization of the gold: and though this sublimation, this evaporation are less marked than those of silver; though gold is really less volatile than the latter, undoubtedly, on account of its almost double density, it, however, elevates itself in vapour; and Macquer has seen it, in the form of smoke, carried to the height of between five and six inches, fixing and attaching itself to the surface of a plate of silver so as to gild it in a very exact manner; accordingly, a small loss is experienced upon the silver and gold that are kept for a long time fused at these high temperatures, which agitate them and reduce them into vapour.

12. Gold has neither taste nor smell, which is owing to the closeness of its molecules, to their density; neither does it present, at least not in so marked a manner, that atmosphere which envelops or surrounds most of the other metallic matters, so well characterized by these two properties which distinguish them. Gold, however, is a very good conductor of the electric fluid, and of that power irritating the muscular organ, which is called galvanism in modern experiments.

C. Natural History.

13. It is still a problem in mineralogy and chemistry, to determine whether gold be mineralized in the globe, or if it be not on the contrary merely disseminated in ores very various in their nature and properties, in which it is contained, and from which it is extracted. Frequently it is in the metallic and brilliant state; but there are so many different minerals in which it is shown, and from which it is extracted, that, in order to acquire a proper idea of its natural history, it is indispensably necessary that we should first treat of the native gold, and afterwards of the gold concealed in the auriferous minerals, of whatever nature these minerals may be.

14. Native gold, so distinguishable by its colour, its brilliancy, and its weight, is found so frequently at the surface and in the interior of the globe, though always in little abundance in general, that Bergman has thought that after iron this metal was the most universally diffused. In the form of small separate masses, of plates, filaments, or grains, it rolls along with the sand in the waters of rivers and brooks which have washed it out of the mountains or soils in which they have their source. In this state it is frequently met with in Peru, in Africa, in France, in Germany. In Africa, five pounds of sand frequently contain sixty-three grains of gold, whereas, in France it is pretty rare
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to find sand which contains more than from twenty to twenty-four grains in an hundred pounds. However, this sand may be worked with advantage. It has even been proposed, indeed, without success, to work a sand of Hungary, of which ten thousand pounds contain only from ten to twelve grains of gold. The most auriferous sand is that of a red or brown colour.

The second state in which native gold is found, is that of particles or fragments, more or less large and perceptible, inclosed in a stony gangue, almost always of quartz, sometimes of jasper, of cornelian, &c. Peru, Mexico, Siberia, Hungary, Tyrol, France, &c. particularly afford it in this state. The form of this native gold varies greatly; it is in plates, filaments, grains, in octahedral crystals, in tetrahedral prisms, in four-sided pyramids, in capillary filaments, or in masses irregularly roundish, which are called *kidneys*. It is this ore of gold which gives rise to the auriferous sand.

15. It is not to be understood that native gold is pure gold; it is alloyed with copper, with silver, with iron, even with mercury: hence arise the so-various colours which distinguish the gold of different countries; the pale yellow, the dark yellow, the reddish yellow, the greenish yellow, the ductile gold, the rigid gold, the pliable gold, the brittle gold; for it presents all these properties in the different pieces of native gold of different countries that
are

are compared together: so that in considering this native gold as a real species amongst the ores of this metal, it is rather amongst the natural alloys that it ought to be placed, in a mineralogical system founded upon the intimate nature of the fossils, which is the only one which the present state of our knowledge allows us to admit.

16. Mr. Kirwan enumerates five species of ores that contain gold, and which he consequently ranks after the only real species of ores of this metal; that is to say, the native gold; namely, the yellow, or martial pyrites, the arsenical pyrites; the white, red, or vitreous ore of silver; the sulphureous ore of silver, of iron, of lead, and of manganese of Transylvania; and lastly, the sulphurated copper and iron with manganese. It is true, he adds at the beginning of each of these articles the words *mixed gold*; which manifestly announces that he considers these ores as so many mixtures, and that he thinks with Bergman, that the gold is only disseminated, not mineralized. Bergman, in fact, observes, according to the examination of several auriferous pyrites, that the gold which is extracted from them by digestion in nitric acid, is in small angular grains, which prove that this metal existed in the state of simple mixture, and not of composition, in the pyrites. Thus the ores of copper, of silver, of lead, of iron, of cobalt, of antimony, from which gold is frequently extracted by docimastic

tic and metallurgical operation, appear to contain this metal simply disseminated amongst their particles; and there is reason to believe, that when these ores are decomposed, effloresce, become sulphatized and dissolved, the gold which separates from them is then carried away by the waters and deposited in the sand as if it were native gold.

17. Perhaps, however, it is necessary to distinguish from these ores in which the gold appears to be disseminated with all its properties, those of Fatzbay, Offenbaya, and Nagyag in Transylvania, in which Born, with several other mineralogists, had at first suspected that the gold was combined with sulphur, antimony, arsenic, iron, and silver, and in which Mr. Klaproth has lately (January, 1798), found the new metal called *Tellurium*, since this metal which had before been taken for antimony, appears to have a great attraction for gold. However, the chemist of Berlin has not yet explained himself upon this subject; and what has been done upon the other auriferous minerals, in which the gold is disseminated, authorizes us to believe that it presents in these the same state of simple mixture. It must here be observed that, excepting the *aurum*, or *metallum problematicum* of Fatzbay, in which the gold is contained only in the very small proportion of two thousandth parts, the ores of Offenbaya contains 0,30, the yellow ore of Nagyag 0,27, and the grey foliated ore of the same place 0,08 and a half.

18. It results, therefore, from what has just been set forth respecting the natural history of gold, that this metal does not exist pure and well insulated in any fossil; that it is always in the state of alloy; that this is even its only state in the globe; that it is frequently disseminated or mixed in other ores, and that neither sulphuret, nor oxides, nor salts of gold are known in nature; which manifestly depends upon the small attraction which gold exerts upon the other natural bodies, and upon the force which condenses its own particles, as will be proved by all the facts of its Chemical History.

D. Assay and Metallurgy.

19. No assays are more simple or more easy to be made than those of the ores of gold, when they are performed only upon what is called native gold; but when sulphureous auriferous minerals are to be treated, we meet with more difficulties: it is by the humid way only that we ought to proceed in it, and the processes indicated by Bergman are those which succeed the best, and which ought to be employed. Native gold, which is generally alloyed with copper, silver, and iron, is treated by the nitro-muriatic acid. The silver is deposited spontaneously in an insoluble muriate, one fifth part of the weight of which belongs to the metal; the gold is precipitated in
a fine

a fine powder by the sulphate of iron ; the iron is indicated by the prussiate of pot-ash, and the copper is separated by the iron : each of these operations is performed upon particular portions of the native gold.

20. The auriferous sulphurets of iron are pulverized : they are then digested in diluted nitric acid, at forty-five degrees of temperature, six parts of this acid being employed at several times for one of ore, till the sulphur is separated pure, and of its natural colour. From twelve to sixteen parts of acid are required for one part of pyrites. The sulphur remains at the surface of the liquor, and the gold is found at the bottom in a brown powder. It is separated from the insoluble gangue by washing ; it is upon these particles of gold that we observe the angular form which announces that they were disseminated in the ore. The other metals, the iron, the copper, the zinc, and the earthy, calcareous, and aluminous gangues, which may exist in the auriferous sulphurets, are distinguished and separated by means of the different processes indicated in the articles which relate to them. The united weights of all the substances obtained separate ought to answer to the total weight of the ore. It is very evident that the same processes may serve for the analysis of all the auriferous minerals of whatever nature they may be.

21. As to the gold-ores of Transylvania, in which Mr. Klaproth has found the new metal, which

which he has called Tellurium, the following is the manner in which he has made their analytic assay. He heated them in six parts of muriatic acid, adding three parts of nitric acid, which he caused to boil; by this means he obtained a complete solution; this solution he precipitated by caustic pot-ash, which he employed in sufficient abundance to re-dissolve the precipitate first formed; there remained brown flakes consisting of oxides of gold and of iron. He poured muriatic acid into the alkaline solution till no more white powder was precipitated, avoiding an excess of this acid: this powder he treated with a fat oil in a retort which he heated to redness. The oxide of tellurium was reduced into white, brilliant, and crystallized metal, of which a part was volatilized, and this he examined particularly, and found to consist in the proportions which I have formerly indicated. Already, before Mr. Klaproth, Mr. Bindheim had analyzed the ore of Nagyag by a process which may have its advantages for finding and extracting the gold, though it did not lead him to the discovery of the particular metal which is contained in it. After having kept the ore pulverized in an open crucible till the whole of the sulphur was burned, he threw the residuum, whilst still hot, into water, and there remained an insoluble matter of a reddish-brown colour. This he digested to dryness in three parts of nitro-muriatic acid; he added ether to it, and agitated it strongly; the

the ether carried off the gold which it reduced, and after it had been evaporated with the aid of heat, this metal remained in a pure and ductile state.

22. The processes employed in the extraction of gold are simple and easy to be conceived, according to all that I have already set forth concerning the metallurgical operations in the preceding articles. The auriferous sand of the rivers is washed with the hand in wooden bowls, by men who are called *orpailleurs*. Native gold requires only to be extracted from its gangue and united: for this purpose it is stamped or ground; it is washed in order to separate the gangue reduced into light powder which the water carries off; it is then triturated in a mill full of water, with ten or twelve times its weight of mercury; the water is decanted, which carries off all that is of an earthy nature. The amalgam, when once separated from the earth, and sufficiently brilliant, is expressed in skins in order to separate the exceeding portion of mercury from the solution of gold. The thick and solid portion which is left after the expression, is heated in retorts of stone-ware, to complete redness, in order to obtain the mercury separate, and the gold which remains is melted and cast into bars or ingots.

As to the gold which is disseminated or combined in the ores of silver, of copper, or of lead, it is extracted by eliquation, cupellation, and the parting assay. The lead which runs during

the eliquation of the argentiferous and auriferous copper, carries along with it the silver and the gold; it is afterwards cupellated in order to scorify the lead. The gold and the silver remain untouched and alloyed with each other; they are separated by the parting assay, which will be described in treating of this alloy. It has been proposed to treat the auriferous pyrites by amalgamation, the success of which, already confirmed in Germany and Peru, proves that the gold exists in them in a simple state of diffemination, and not combined.

23. Of all the metals hitherto known, gold is the most indestructible and the most unalterable by the contact of the air; it is the only one which preserves its lustre, its brilliancy, its colours, and all its purity; the only one which resists the effects of accumulated ages. The gildings of all public edifices, which chemists generally quote in demonstration of their unalterability of gold by the air and the vapours which it carries with it, are but weak examples in comparison with those stars of gold attached to the ceilings of temples built thousands of years ago by the Egyptians, which modern travellers have recently seen shining in all their lustre upon the ruins of those immense edifices which have escaped for so many centuries from the scythe of Time. With respect to this beautiful property, gold is far superior to silver, which assumes a black colour by long exposure to the air.

24. However

24. However intense or durable the heat of the furnaces may be in which gold is kept fused, it is not sufficient to alter it or convert a single particle of it into oxide. Clavius, Kunckel, and Boyle, have kept gold in this manner, during whole months, in the state of fusion, in the most intense heat of furnaces, without finding that it underwent any alteration. Citizen Baumé asserts, that he has kept for a whole year leaf gold triturated into a fine powder, and continually heated to redness, in a vessel into which the air penetrated, without it experiencing any sensible alteration. The alchemists, however, have pretended that, by the fire of a reverberatory furnace, this metal was susceptible of being oxidated. It is remarked that when gold is well fused and at the white heat, it presents at its surface a very perceptible greenish or water-coloured flame. But it is at present evident, that when it had not been made to experience any change in the experiments, it was because a sufficiently-elevated temperature had not been employed, as is proved by the following results.

25. Homberg, having exposed pure gold to the focus of the lens of Tschirnhausen, saw this metal emit fumes, become reduced into vapour, and covered with a violet-coloured vitrified oxide. This fact had been attributed to extraneous bodies, and especially to the charcoal which served to support the gold, till the time when Macquer repeated the experiments of Homberg with the new lens of the academy, which

which is much stronger than that of Tschirnhausen. After having verified the volatilization of the gold into smoke, and seen it, under the focus of this mirror, agitated by a rapid intestine motion, he observed that it became covered with a dull and wrinkled pellicle, that in the course of time a solid vitrification formed itself in this kind of covering, forming a portion of a sphere smaller than the globule of gold, and as it were set in it like the transparent cornea upon the ball of the eye. This vitrification gradually extended itself and formed a very visible knob, whilst the gold at the same time diminished; the support was always impregnated with a purple mark manifestly owing to a small quantity of glass absorbed. Thus it cannot be doubted that the gold is oxidized by this process, especially when we find by other states of this metal that it is susceptible of frequently assuming this form of brown or deep purple powder; a colour, which is one of the indications by which we recognize its oxidation with the greatest certainty.

26. Citizen Comus was the first who described, in 1773, the effect of electricity upon a leaf of gold placed between two cards, and showed that it was changed into a violet powder, which appeared to him to be a *calx* of gold, as the metallic oxides were then termed. It had been already for a long time known that gold assumes the same colour by the contact and ebullition of the nitric acid in the parting

assay, and that it communicates it to the enamels in the glazing and paintings upon porcelain; but chemists, nevertheless, did not consider those changes of the gold as the products of an oxidation, since they saw these colours easily and quickly converted again to the brilliancy of gold by the action of fire. They were therefore led to consider this oxidation as a simple division of the metal, till Citizen Van Marum had found in the powerful effects of the electrical machine of Teyler, the means of burning gold with such lustre that its real combustibility could no longer be a subject of doubt. A gold wire, suspended in the air, and placed in communication with an electric conductor, in such a manner as to cause the electric shock to pass through it, is broken, kindled with a very perceptible green flame, and reduced into a powder, which the air carries off like smoke; it even requires but very little air to favour the combustibility of gold; some have even gone so far as to infer from the inflammation of this metal effected by the electric spark in receivers full of hydrogen gas and other elastic fluids which cannot be subservient to combustion, that this experiment might afford a strong objection against the pneumatic doctrine; but the discovery of the decomposition of water by electricity, and the constant presence of this liquid in most of the gases, have destroyed this objection. It is likewise known that this oxidation of gold into the
violet,

violet colour, takes place upon gildings which are struck by lightning when it falls upon houses.

27. The oxide of gold, formed by the different processes which I have just indicated, is easy to be reduced; it has but little adhesion with the oxygen which is united with it. The mere contact of caloric is sufficient to disengage it, and to reduce the oxide, more or less quickly, into the metallic state. It appears that this purple oxide contains about five or six parts to the hundred of oxygen; that this is not the last term of the oxidation of gold, that it may be brought to eight or ten to the hundred of oxygen, as I shall show hereafter; that it is impossible by the mere action of the air, of a high temperature, and of the electric commotion, to push this oxidation of the gold farther than to the violet state; that the purple oxide of gold, obtained in such small quantity, and with so much difficulty by those processes, is not capable of absorbing from the air the portion of oxygen with which it may be combined in other chemical operations; that it is consequently unalterable by the air, and that it preserves for a long time its brilliant and rich colour; and that long exposure to the light of the sun, when this oxide is not engaged in a vitriform combination, decomposes and reduces it to the metallic state.

F. Union with the Combustible Bodies.

28. THERE are many combustible bodies with which gold may combine; but azote, hidrogen, carbon, sulphur, and the diamond do not form any combination with it. Hidrogen easily reduces its purple oxide, and even its more advanced oxides of which I shall shortly speak. It has been believed that charcoal powder upon fused gold rendered it brittle; but the processes that are employed in some mints, in which charcoal is thrown into the crucibles while it is fused, prove the contrary. Sulphur has so little attraction for gold, and so much for the other metals, that it has been employed for separating these, and especially silver, from gold, as I shall show in speaking of the alloys of the latter metal. The alkaline sulphurets have the property of dissolving gold with facility. When we fuse in a crucible equal parts of pot-ash or soda, and of sulphur with an eighth of their total weight of gold in leaves, this metal combines with the sulphuret and disappears. This matter, poured upon a plate and dissolved in water, presents no trace of metallic gold. The whole is soluble in water; we can precipitate the sulphur and the gold by the acids, and obtain the gold pure and insulated by heating the precipitate in a crucible till the sulphur is volatilized. It cannot be doubted, that in this combination the gold

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is in the state of purple oxide, and that its oxidation is favoured by the decomposition of the water owing to the alkaline sulphuret. It is difficult to explain how Stahl could have written a serious dissertation upon the pretended solution of the golden-calf of the Israelites, in order to prove that Moses made this solution by means of the sulphuret of pot-ash or *liver of sulphur*.

29. Pelletier has proved that phosphorus combines with gold by heating in a crucible a mixture of one part of gold in fine filings, with two parts of vitreous phosphoric acid and an eighth of carbon; a large part of the phosphorus disengaged from the acid was volatilized; but there remained a small quantity united with the gold: this metal was whiter and more brittle; it had an appearance of crystallization; it appeared to contain only one twenty-fourth of its weight of phosphorus. He also succeeded in combining phosphorus with gold, by throwing the phosphorus upon the metal heated to redness in a crucible; he had the same result as in the first experiment: the gold took up one twenty-fourth part of its weight of phosphorus. It became pale, granulated, brittle, and a little more fusible than it was before. The phosphorus separates from it in vapour and with inflammation, when the phosphuret of gold is kept for some time in fusion.

30. Gold is susceptible of being alloyed with most of the metallic substances, which singularly change

change its properties. Arsenic renders it eager, brittle, difficult to be filed, of a granulated texture, and especially very pale; it becomes at the same time very grey by this kind of alloy. The arsenic is separated from it by the action of fire, but it is necessary that it should be strong and long continued, because the last portions of arsenic adhere very strongly to this metal. This alloy has not yet been applied to any use.

The union of gold with tungsten, molybdena, chromium, titanium, uranium, and manganese, has not yet been examined.

31. The combination of gold and cobalt is not sensibly different from the latter metal in its pure state, according to the chemists who have spoken of it. Wallerius says that this alloy, reduced into fine powder and heated with the contact of the air, yields, after its oxidation, by an intense heat, an auriferous glass of a dark blue colour.

Cronstedt, speaking of the combination of nickel with gold, says nothing more than that it affords a white and brittle mass.

32. Bismuth, fused with gold, also affords a brittle alloy, the brittleness of which is in proportion to the quantity of the bismuth employed. It is added, that the specific gravity of this alloy is greater than the mean, which would result from the weight of the two metals combined.



33. Anti-

33. Antimony combined with gold also renders it eager and brittle. This alloy, made with equal parts, does not differ much from gold in its appearance, according to some authors. The alchemists have frequently employed this combination in their researches. They called the antimony by the ridiculous names of *bath of the king*, *royal bath*. They pretended that the quantity of gold was augmented when it was separated from the alloy, after having been fused with this metal, but accurate experiments have proved the falsity of this assertion, and that it proceeded from their not having entirely purified it, but left in it a surplus of antimony. The sulphuret of antimony was formerly much employed for refining gold, for separating from it, with the aid of sulphur, the metals that were united with it. It was because the sulphuret of antimony acted in this manner upon all the metallic substances, excepting gold, that this mineral was called, in the language of the alchemists, the *wolf of metals*. When the gold has been separated from the metals that alter it, by means of the sulphuret of antimony, we obtain the gold alloyed with antimony, and it may be purified or refined by keeping it for a longer or shorter time in fusion, and at last completing the oxidation of the antimony by means of nitre. It is frequently in order to separate tin or iron from the gold, which cannot be separated from it by cupellation with lead or bismuth, unless with
great

great difficulty, that the sulphuret of antimony is employed; but there are several other means of effecting this separation, as I purpose to show.

34. Gold unites very easily with mercury. Citizen Guyton has found that of all metals it is that which, when applied in a plate upon running mercury, requires the greatest effort to separate it from it; this effort he represents by the number 446, whereas, it required only a weight equal to 429 to separate silver, as I have said elsewhere. As soon as mercury touches gold, it flattens, extends itself over every point of its surface, penetrates it, covers it exactly, and causes its colour to disappear. All artists who employ mercury in their operations are well acquainted with this effect, and carefully avoid all contact between the two metals. A plate, an ingot, a vessel, any utensil, of gold, when plunged for some moments into mercury, is penetrated by it to such a degree as soon to become brittle; if left in it for a long time, it softens and is entirely dissolved. Accordingly, mercury has been reckoned amongst the solvents of metals. When we triturate leaf gold with mercury, the leaves are very quickly condensed, and suddenly drawn into the mercury which absorbs them; in this manner we may charge mercury in the cold with the whole quantity of gold with which it is capable of uniting. Wallerius has remarked, that one part of gold has the property of coagulating

coagulating ten parts of mercury. When we augment the proportion of gold, the amalgam becomes solid. When the operation is performed in the large way, as in the workshops of the gilders, the combination of the mercury and gold is promoted by the action of a gentle fire. This amalgam saturated with gold is of a more or less intense yellow colour; it is fusible by a mild heat, and crystallizes by cooling into leaves or quadrangular prisms, or dendrites composed of small octahedrons: a strong heat decomposes it and disengages the mercury from it, but the last portions cannot be extracted from it without difficulty. No metal separates gold from mercury, and it appears on the contrary that gold is capable of carrying off mercury from the other metals.

Though gold, as I have shown, is very difficult to be oxidated by the air assisted by the action of fire, the alchemists had announced a long time ago that it might be *calcined* by the mediation of mercury. Citizen Baumé asserts that he has succeeded in this experiment. It consists in putting mercury, containing a forty-eighth of its weight of gold into a matrafs with a flat bottom, and with its neck drawn out at the lamp and broken off at its capillary extremity; this vessel is placed upon a sand-bath, and heated as is done with mercury alone when it is desired to convert it into red oxide, which was formerly called *precipitate per se*, that is to say, it is kept slightly and continually

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boiling

boiling for several successive days. According to the chemist above mentioned, the two oxides of mercury and of gold are obtained at the same time, and within a shorter space of time than is required for the oxidation of the mercury alone. This phenomenon, if confirmed by new researches, will prove that the division of the gold, effected by the mercury, singularly favours its combination with oxygen, and that even, when united together, these two metals mutually accelerate their own oxidation.

The amalgam of gold is particularly employed for gilding upon silver, copper, and even iron.

35. Gold easily unites with zinc by fusion: the result of this union is an alloy which is paler than the gold, little-malleable, frequently even entirely brittle, if the proportion of the zinc be somewhat considerable. This alloy, made with equal parts of the two metals, is of a specific gravity above the mean, and affords a very eager metal, of a fine and close grain, very hard, susceptible of a beautiful polish, little alterable by the air, and which, on account of these properties has been recommended by Hellot for making telescopic specula. If we unite one part of gold with ten of zinc, and inflame this fused alloy in a crucible, the zinc, sublimed into the air, carries the gold along with it, according to the remark of the ancient chemists, who have likewise applied the same remark to antimony: on this account they have advised
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not to heat the auriferous antimony too violently, in order that no sensible portion of it may be lost. Gold alloyed with zinc is easily separated by all the acids, which dissolve the latter of these metals with effervescence, without touching the first. However, the last portions of the zinc are defended against the action of the acids by the gold; on this account the action of nitre ought to be joined with that of the acids. It has been observed, that zinc does not pass easily in the cupel, but rather elevates itself above the gold in an oxidated fungus, when we attempt to carry it off by the lead. It is in this case that bismuth has been advised; but it does not succeed more completely.

36. Gold combines very easily and quickly with tin, by fusion. This alloy is dreaded by all artists who work upon gold, as it deprives it of all its ductility, they even are apprehensive of exposing gold to the contact of the mere vapour of melted tin, which is asserted to be equally capable of rendering gold very brittle. In fact, this alloy is so brittle that it may be reduced to powder by triturating it in a mortar. According to Wallerius, this powder, heated in contact with the air, grows black and afterwards white, it does not become either yellow or red; no molecules of gold are discernible in it with the strongest magnifying glasses; even after the oxidation has been carried very far, mercury can no longer separate the gold from it. When we vitrify this mixed oxide, we obtain

obtain a yellow glass; at the same time there is separated from it a portion of metal composed of tin and gold, as observed by Brandt. The same alloy is less dense than is indicated by calculation from the two metals, according to the experiments of Kraft.

Whatever care may be taken to avoid alloying gold with tin, this alloy is frequently met with by the goldsmiths, on account of the jewellery soldered with tin, which, though scraped before it is fused, always retains a sufficient quantity of it to deprive even considerable masses of gold of their ductility. This gold, altered by tin, is very difficult to be purified and rendered properly ductile. The tin does not pass in cupellation with lead; nor even with bismuth; nitre, borax, and even super-oxigenated muriate of mercury which are so frequently employed with this intention, do not always succeed in refining it. If it be softened by these different means, it still frequently retains the defect of cracking and flaking under the hammer. There is no better process for effecting this refining than treatment with the sulphuret of antimony. We may also employ the action of the muriatic acid, which dissolves the tin when it is applied in a pretty considerable proportion.

§ 37. Lead easily unites with gold, by fusion, and does not deprive it of its ductility as much as tin, though it sensibly impairs it; the colour of the gold is much altered, and becomes dull.

See also

Juncker

Juncker asserts, that by fusing lead in a vessel with a narrow orifice, upon which gold was placed exposed to the vapour of the former metal for the space of an hour, the piece of gold was rendered friable. The alloy of gold with lead is one of those which are purified and decomposed with the greatest facility, on account of the very easy oxidability and vitrification of the lead. It is sufficient to keep it for a long time fused and red, in contact with the air, especially in a porous vessel capable of absorbing the vitrified oxide of lead, in order entirely to deprive the gold of the admixture of this metal. This is also what is done in the cupelling of gold: this cupellation, which greatly resembles that of silver, presents only one difference, namely, that it can, and even ought to be performed with a stronger fire, because the lead relinquishes the gold more slowly, which strongly retains its last portions, and because the gold, which resists the fire much more powerfully, is less subject to suffer waste than the silver.

§ 38. Iron easily unites with gold, and forms with it a hard and brittle mass. Lewis found some of these alloys so hard, that he has asserted we might make razors of them. Equal parts of iron and gold afford a grey mass; four parts of iron and one of gold form an alloy which has nearly the colour of silver. Gellert has observed, that this alloy has a specific weight inferior to that indicated by the sum of the densities

densities of the two metals. Fused gold adheres very easily to iron: it has therefore been proposed to folder small pieces of steel with gold, and it has been remarked that this foldering is far preferable to that with copper. Gold altered by iron is very difficult to be purified; bismuth only is capable of carrying it off by cupellation: lead is inadequate to carry off the iron. The sulphuret of antimony is particularly well adapted for this separation, on account of the great attraction of iron for sulphur.

39. Copper combines intimately and easily with gold by fusion. This alloy is one of the most common, as it is that which gives the most solidity or hardness to gold, which is itself too soft to be employed alone, and pure for the different fabrications for which it is destined, and as instead of weakening or concealing the colour of the gold, it very sensibly augments and heightens it. Muschenbroeck has made a series of very interesting researches relative to the alloys of gold and copper. According to him, the proportion which gives gold the greatest firmness without sensibly diminishing its ductility, is that of one part of copper to seven of gold. This alloy is more fusible than gold; it is also especially employed for foldering pieces of the latter metal to each other. When we wish to purify gold and separate it entirely from the copper which it contains, it is treated by cupellation with lead; the latter metal, as it becomes

becomes oxidized and vitrified, easily carries off the copper, which becomes oxidized at the same time, and combines with the glass of lead, which causes it to pass into the pores of the cupel. Sometimes also nitre is used, which is thrown upon the alloyed metal in fusion; but this process does not extract, without great difficulty, all the copper united with the gold. Citizen Briffon has found that a mutual penetration takes place in the alloy of gold and copper, and that the specific gravity of the mixture is greater than the sum of the specific gravities of the two metals separate. Thus gold of the Paris standard, that is to say, containing one part of copper to eleven of gold, gives as its specific gravity 17,486, whereas if no penetration took place between these two metals, it ought to be very nearly 17,153; which makes an augmentation of density of about $\frac{1}{17}$.

40. Silver unites well with gold. Homberg has remarked, that when equal parts of these two metals are fused in a crucible, they easily separate, though the gold which sinks to the bottom retains however about a seventh part of its weight of silver. Justi has pretended that these two metals might be separated by mere fusion, continued for a long time; but this process is far from deserving the eulogiums which its author has bestowed upon it: the gold always retains some silver, and the silver a little gold; so that it may be said, that these two metals separate into two different alloys, the

inferior of which is argentiferous gold, and the superior auriferous silver. When these two fused metals are well agitated, they form a homogeneous alloy. I have already remarked in another place, that silver greatly weakens, and entirely covers the colour of copper. Gellert has observed, that the alloy of gold and silver suffers only a slight augmentation of specific weight. Muschenbroeck has found that one part of silver gave to two parts of gold the greatest possible consistence or firmness. As to the colour, it is very remarkable that a twentieth part of silver produces a great change in gold, and whitens it in a very striking manner. It is also to be observed, that the addition of silver gives rigidity, elasticity and hardness to gold. With this alloy, yellow, pale, and green gold, are made for jewellery. Formerly this alloy was much more used in goldsmiths work, and in coins than is now done; it is still employed for foldering gold, and for enameller's plates, and it is frequently met with in the silver and gold of commerce, which requires to be refined. All the gildings, and whatever goes in the shops by the name of gilt, are alloys of gold and silver, of which it is necessary exactly to know the proportions, and essential to separate the two metals. After having passed them in the cupel with lead, they are treated with nitric acid, which dissolves the silver without attacking the gold: this operation is one of the most important in the docimastic art, one of these which
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most merit to be well known; it is highly interesting in all the arts which are exercised upon gold and silver.

41. Though the name of the *parting assay* is applied in general in chemistry to every process of which the object is to separate metals from one another, this denomination is more particularly applied to the alloys of gold and silver, because these two metals, being more important and more valuable than all the rest, require a degree of care and attention which those do not. There are different processes for parting a mass composed of gold and silver. In general we begin by endeavouring to ascertain the nature and the proportion of the alloy, by the application of a simple means, but which requires much exercise and habit in order to succeed in it; accordingly in the workshops this operation is often committed to one particular person. It is founded, like the parting assay itself, upon the solubility and oxidability of silver, and the inalterability of gold. It consists in rubbing the alloy upon a hard stone, or piece of jasper, which receives a mark from it, upon which some drops of aqua-fortis are poured; if it be only silver the whole is carried away; if it be only gold the mark remains entire: what remains, compared with what has been taken away, serves to determine the standard of the gold. It is evident that the same means will serve equally for gold alloyed with copper; it is oftener employed for the latter alloy, which is much more

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frequent than the first in goldsmiths work. We may become accustomed to judge skilfully from this first assay by the touch, or by the touch-stone, by beginning to practice with known alloys of all possible proportions, which are called touch-neededles. Even the colour of the mark left upon the stone by the alloy, indicates to experienced persons the nature, or at least very nearly the proportion of its parts. But though this first assay is sufficient to enable us to judge of very small pieces, though it affords a first notion sufficient to guide us in the operation which precedes that of parting the alloyed mass, it is far from being satisfactory for those who wish to ascertain with precision the nature of the alloy of gold and silver.

42. There are several processes for making the parting assay of an alloyed mass of gold and silver: there are particularly distinguished the *dry parting*, the *parting by cementation or concentrated*, the *inverse parting*, and *parting by nitric acid, or aqua-fortis*. The first is made by means of sulphur; the second by a mixture of sulphate of iron and sea-salt, which are cemented with leaves of the alloy in a crucible: it is the oxygenated muriatic acid which here acts upon the silver. The inverse parting is made by the nitro-muriatic acid, which dissolves the gold, and reduces the silver into insoluble muriate. The three first kinds of parting are rarely used, because they are either embarrassing or not sufficiently exact: it is the parting
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ing with the nitric acid which is the most employed, because the most simple and the most certain. In order to perform the ordinary process of parting, that which is subsequent to the touch, and ought to afford a positive knowledge of the nature of the alloy, it is first necessary that the proportion of the silver be at least double that of the gold. Most assayers require even that the silver should form three fourths of the alloy; on which account silver is frequently added to the mass: this is called *quartation*. When this addition has been made, when the alloy, having been well cupelled, contains nothing else but silver and gold, the button, which is generally taken of three grammes, or two dwts is flattened upon a steel anvil; it is passed through the flattening machine, taking care to anneal it, in order to prevent its cracking, and that the plate which is obtained may be perfectly entire: this plate is made sufficiently strong to resist and to preserve its form, though thin enough to be easily bended; it is rolled upon a pin, or upon a mould of iron made expressly for the purpose; it is formed into a cornet, which is introduced into a small conical matrass: upon this is poured about seven or eight times its weight of well-purified nitric acid, or of precipitated aqua-fortis at 32 degrees of the areometer, diluted with one half of pure water. The vessel is placed upon a sand hearth till the effervescence and the disengagement of nitrous gas are well established; it is heated gently as

long as red vapours arise; when they arise no longer, and when the effervescence ceases at the moment in which the matrafs is removed from the fire, the operation is terminated, the silver is for the greater part dissolved, and the gold remains with the form of a cornet or coil, and of a deep purple colour. However, in order to be certain of carrying off all the silver and not leaving a surplus of this metal in the gold, after having gently decanted the first acid from above the cornet, four more parts of nitric acid at 30 deg. are poured upon it and boiled for some moments: this second operation, which is intended for taking away all the silver from the gold, is called the *reprise*. The acid is again decanted with caution, in order to preserve the cornet of gold entire; the cornet which has become very thin and perforated with many holes, is then washed with pure water; it is afterwards made to fall with water, (the matrafs being cautiously turned) into the bottom of a small crucible, in order to favour the sliding and falling down of the cornet of gold, along the sides of the matrafs, without endangering its breaking; the water is then evacuated, and the metal annealed or heated to slight redness, and it resumes its brilliancy and beautiful colour; it is then weighed with very exact scales, and the quantity of the alloy, and also the standard of the gold, is determined by the weight which it has lost. In order to give a very accurate expression of this standard, the quantity of
gold

gold which has been assayed, is divided into decimal parts, and with the aid of very small weights, the slightest loss that has been sustained is known. Formerly this mass of gold to be assayed was supposed to be divided into twenty-four parts, which were called carats, and each part into thirty-two others, which were called thirty-seconds of carats. The carat, in the effective weight, which was called in French *semelle*, was one grain mark-weight; so that the thirty-second of a carat was a thirty-second part of a grain. Sometimes the carat represented only half a grain in the weight called *demi-semelle*, in which case the thirty-second of a carat was only a sixty-fourth of an effective grain.

43. Some chemists have thought that in the parting assay of gold alloyed with silver, a little gold was dissolved, as seemed to be announced by the deep purple colour of the cornet which remains; but it has been ascertained that this quantity is so small that it cannot be a matter of interest or alarm in commerce: I shall return to this fact in another place in the history of the treatment of gold by the acids. Several able assayers, especially Cramer, Schindler, and Schlutter, have thought, that the cornet of gold of the parting assay, retains a small quantity of silver, which they have called *Hinterhalt*, or *surcharge*; Hellot, Macquer, and Tillet, on the contrary, affirm that it does not contain any sensible quantity of it. Citizen Sage, however, says, that the gold of the parting
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ing assay, dissolved in the nitro-muriatic acid, always precipitates after some hours a small quantity of muriate of silver.

44. In the parting operation, upon the large scale, the same precautions are not taken as in the parting assay, because it is not the exact proportion of the two metals which is wished to be ascertained, but only to obtain the gold refined and pure. We are content with casting the gold alloyed with silver into small portions or grains, and putting it into matrasles with flat bottoms, or even into bottles of stone-ware; then pouring upon it twice or thrice its weight of nitric acid, at 38 or 40 degrees; heating it over a gentle fire; and decanting the liquor when the signs of solution have ceased, that is to say, the motion of effervescence and the disengagement of nitrous gas; then pouring on a new small quantity of acid, which is boiled, upon the residuum; re-commencing this ebullition a third time with a third addition of acid, in order to be certain of carrying off all the silver; washing the gold several times with much water; and lastly, fusing the gold which remains at the bottom of the vessels in the form of powder and of deep purple fragments, in crucibles in which a little nitre is thrown: this is what is called *parted gold*. It is in this operation, which constitutes the refining of gold, that the pure silver is at the same time prepared, which is also known by the name of *parted silver*. In order to obtain it, the nitric acid proceeding
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from the parting and the waters of the lixiviation of the gold, are poured into dishes of stoneware; the liquid is diluted with a large quantity of water; a plate of copper is plunged into it, and suffered to remain for forty-eight or sixty hours: the blue liquor, or the solution of copper, which has been formed, is then decanted; the metallic silver deposited by the copper in small crystallized and brilliant grains, is washed with a large quantity of water; it is ignited again in order to obtain what is improperly termed *silver in calx*, or it is fused and collected with the aid of nitre, which also purifies it, in order that it may be cast into ingots. The blue liquor, or the nitric solution which results from this precipitation of the nitrate of silver of parting, is particularly employed in England, in the preparation of verditer by its mixture with slaked lime: it has even been pretended, that it succeeds better than the simple immediate solution of copper, which has been attributed to a small quantity of silver remaining in it; but this erroneous notion has been confuted by the experiments of Pelletier.

G. *Action upon Water and the Oxides.*

45. It is well ascertained that there is no action between gold and water; and the attraction of this metal for oxygen is too feeble for it to be capable of taking it away from the hydrogen.

gen. There is, however, one case in which gold appears to unite with the oxygen of water, but without its attraction for this principle being the cause which determines its decomposition, or the separation of the oxygen and the hydrogen: I mean that in which these two bodies are exposed at the same time to the electric commotion. It has been believed for some time, after the brilliant experiments of Citizen Van Marum, upon the inflammation of the metals by this commotion, that this inflammation might take place in vacuo, or in other gases beside the atmospheric air. This phenomenon, which seemed to be well verified, had even been adduced as a specious objection against the French or Pneumatic doctrine, when it was soon discovered that the water was decomposed by the electric spark, and separated into its two gaseous elements: thenceforward there was no longer any obscurity in the experiments by which the inflammation and oxidation of silver, of gold, and of many other metals, in vacuo, or without oxygen gas, was thought to be effected. It was perceived that the water in vapour, dissolved in the gases, and decomposed by the electricity, afforded to these metals the oxygen which they required in order to burn; and so far from remaining an objection against the pneumatic chemistry, this phenomenon, when well understood, becomes one of the strongest proofs, one of the most substantial bases of this doctrine whose validity is now established.

established. There is reason to believe that it is by a similar pre-disposing attraction, and with the aid of the previous decomposition of the water, that the alkaline sulphurets so easily oxidize and dissolve gold; a solution and oxidation which hitherto it has been impossible to comprehend and explain.

46. Gold has no direct action upon the metallic oxides; far from being able to change them, and deprive them of the oxygen which is united with them, the oxide of gold on the contrary yields its own to all the other metals; accordingly we see these quickly, and more or less completely, deprive it of this principle, and cause the gold to appear again in its brilliant and metallic form, as takes place in its solutions. It is not even necessary for this purpose that the greater part of these metals, those especially which are very greedy of oxygen and susceptible of absorbing a large quantity of it, should be themselves in the metallic state; it is often sufficient that they only are not completely saturated with it, as we observe in tin, iron, and lead, in order that they may be able to take from it either the whole or only a part of that which is united with it. We shall soon exhibit several examples of these interesting effects. There are also cases, in which the oxide of gold, sharing only a portion of its oxygen with other metallic oxides, remains with them in combinations which it colours with different shades; this I shall point out hereafter in speaking

ing of the composition of enamels, of coloured glasses, and of the glazing of fine pottery.

H. *Action upon the Acids.*

47. THERE is a great difference between gold and silver in the manner in which the first resists most of the acids, whilst, as we have seen in the preceding article, silver is easily oxidated and dissolved by several of them. The most concentrated 'sulphuric' acid, assisted by the strongest heat, the sulphureous acid, the muriatic, the phosphoric, the fluoric, or any other acid, have no action upon gold, however long we may leave them in contact with it, and in whatever manner we may treat it; there are only the nitric, the nitro-muriatic, and the oxygenated muriatic acids, which have either a slight or a strong action upon this metal.

48. It was Brandt who discovered, in some measure by chance, and by endeavouring to effect the parting of gold and silver by the concentrated nitric acid, poured several times successively, distilled to dryness, and boiled upon the gold which remained after the silver, that the first of these metals was dissolved and gave a fawn colour to the acid, till there was more gold than silver dissolved in the last portion of acid that was added, since the proportion of the first was to that of the second as nineteen to twelve. This experiment was several times repeated

peated before the Swedish Academy, and constantly with the success which the author had announced. The nitric acid was very pure; the gold was precipitated in the metallic and spongy state by silver which he immersed in it. Lewis, in quoting this result, attributes it to the extreme concentration of the acid pushed to dryness: Scheffer and Bergman have confirmed it. However, it has been ascertained in France, even by the experiments of Citizen Sage, who had concluded that in the parting the gold was a little attacked; that this solution is very weak; that in general the gold lost but very little of its weight; that when it was in a mass it was scarcely attacked; that in the state of a thin plate, or a fine powder, it was more so; that it then assumed a deep purple colour; that the considerable solution announced by Brandt, proceeded only from the concentration of the acid almost to dryness, and that nothing similar took place in the parting operation. Citizen Deyeux has since made another interesting observation on the solubility of gold in the nitric acid; namely, that this acid dissolves it so much the better in proportion as it contains more gas, or rather a larger quantity of nitrous oxide, and that it then acts upon this metal like a kind of nitro-muriatic acid, its true solvent, as I shall shortly show. Tillet, who would not believe in the solubility of gold in the acid of nitre, thought that the loss of weight which this metal suffered in this acid

acid was only the consequence of a mechanical effect, that the gold was, as it were, rasped or filed by the action of the acid, and that it was only suspended in it instead of being dissolved; but the facts which he adduced in proof of his assertion evidently demonstrate the contrary. The nitric solution of gold, exposed to the light of the sun, is in fact decomposed, and we soon see small lamellæ of shining gold, which the contact of the light has disoxidated. This solution, when filtrated, leaves upon paper a violet-coloured mark which indicates the oxidation of the gold; the alkalis precipitate from it a real oxide; and a plate of tin, as well as a plate of silver or running mercury, also cause a purple powder to be deposited in it. Other experiments upon this subject have shown me that gold in fragments, or in thick plates, as well as in leaves, is dissolved by the nitric acid surcharged with nitrous oxide, and that the oxidation which the gold suffers is owing to this nitrous oxide; that it is this which yields oxygen to it as being more decomposable than the nitric acid; that it is on this account that the acid loses its colour on being agitated upon gold; that this solution is better effected in the cold than with the aid of heat, because the heat disengages the nitrous gas; that in proportion as the gold is oxidized and dissolved in the acid, this, after having been first rendered colourless, afterwards re-assumes an orange colour; that there is then formed a real nitrate of gold with
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excess of acid; which cannot be obtained crystallized, and is decomposed by heat and light; that this nitrate of gold in solution is decomposed by the muriatic acid, which, at the moment when it is added, causes the colour of the solution to pass from the orange to the pure yellow: thus the muriatic acid has more attraction for the oxide of gold than the nitric acid has.

49. The muriatic acid has no action either upon gold or upon its purple oxide; but the oxygenated muriatic acid oxides it very quickly and dissolves it. As soon as a plate or leaves of gold is immersed into oxygenated muriatic acid gas, the gold becomes dull, without, however passing into the violet colour, but quickly arrives at the state of fawn-coloured or yellowish oxide; for it is only in this second state of oxidation that gold is soluble in the acids and capable of forming salts with them. When it has become thus yellowish by union with the oxygen, the muriatic acid, by the aid of the water contained in the oxygenated muriatic acid gas, is condensed into yellow drops which run down upon the sides of the vessel in which the experiment has been made. If a little water be added we obtain a complete solution. When we throw gold highly divided, and in leaves, into liquid oxygenated muriatic acid, this metal, by the slightest agitation, disappears, is dissolved without motion and without effervescence, imparts to the liquor a beautiful yellow colour, and saturates

turates it. If there be silver in the gold, the smallest quantity of this mixture becomes perceptible in this experiment, as there is formed a small quantity of muriate of silver, which is deposited in small flakes. I have constantly found a little silver, and sometimes even a larger proportion than should have been expected, in the leaf-gold, in books which are purchased from the gold-beaters. I have also found this to be a very good means for ascertaining whether the gold of the parting retained any silver. This solution, which was discovered by Scheele, is performed without any disengagement of gas, because the gold finds the oxygen almost insulated, and does not require to separate it from any other body susceptible of assuming the gaseous form; moreover, it is perfectly similar to that which is made with the nitro-muriatic acid, or in the ordinary manner: like this, it is acrid and caustic, tinges organic substances with a purple colour; it affords crystals, and is precipitated in a purple form by tin, and into fulminating gold by ammonia.

50. Whenever the nitric acid, which dissolves gold only with difficulty and in very small quantity, is mixed with muriatic acid, which never dissolves it alone, the compound that results from the mixture attacks the gold with an activity and energy which must have greatly astonished chemists before its real cause was known. Accordingly, in consequence of the precedence and superiority which they attributed

buted to gold, which they, therefore, called the *king of metals*, they had granted another name to the liquid that was capable of dissolving it, and which they thought to be exclusively adequate to produce this effect. It has already been seen that the oxygenated muriatic acid produces the same solvent action upon gold; and that even the nitric acid partakes of it, though in a less marked degree. In order to afford a clear idea of the action of the nitro-muriatic acid, I shall first observe that the muriatic acid, saturated with nitrous gas, which it easily absorbs, becomes equally capable of dissolving gold, though nitrous gas alone and muriatic acid alone cannot act upon this metal; and as, at the moment when this nitrous muriatic acid attacks the gold, it loses the orange colour which it had acquired by the absorption of the nitrous gas, it is evident, that this oxide of azote is decomposed, that it yields its oxygen to the gold, that its azote is separated from it, and that this decomposition which oxidizes the gold takes place only by the disposing attraction which the muriatic acid exerts upon the metallic oxide. This fact, which had not yet been observed by chemists, will serve me to explain the action of the nitro-muriatic acid upon this metal. When we mix nitric acid and muriatic acid, the latter takes away oxygen from the former, and escapes in part in oxygenated muriatic acid, distinguishable by its yellow colour and its smell; it only effects this decomposition

position until the nitric acid is saturated with nitrous gas: there its action upon it ceases; so that the mixed acid which results is only a mixture of muriatic acid and of nitrous acid saturated with its oxide, frequently retaining a small quantity of oxygenated muriatic acid, having an exalted red colour on account of the nitrous oxide which it contains. This mixed acid is generally made by mixing two parts of nitric acid and one of muriatic: I have found that it is sufficient if we take equal parts of these two acids. It is well known that an analogous liquor is obtained by dissolving muriate of soda or of ammonia in nitric acid, or nitrate of pot-ash in muriatic acid, or by distilling the latter in the acid of marine salt, and that in whatever manner we combine these two acids with each other, there is always a mixed acid capable of dissolving gold. However, there are two improvements to be made in the process of dissolving gold by the nitro-muriatic acid: the one is, to employ only one part of nitric acid, instead of two, to one part of muriatic; the other, not to make the mixture before dissolving the gold; for when this mixture is made beforehand, the portion of oxygenated muriatic acid that is formed is dissipated, and this is so much loss for the solution of the gold. I therefore prefer to throw nitric acid upon the gold, and afterwards to add an equal part of muriatic acid; the latter acid then, in proportion as it takes away oxygen from the nitric acid,

acid, yields it immediately to the gold instead of its being dissipated into gas. When we put gold into nitro-muriatic acid made beforehand, and in which the reciprocal action of the two acids is exhausted, the muriatic acid, by virtue of the strong attraction which it has for the oxide of gold, causes the nitrous oxide to be decomposed, which colours the liquor as well as the acid itself by this metal, and dissolves the oxide as fast as it is formed; accordingly, the liquor loses its orange or red colour; it becomes heated because a condensation, an approximation of molecules takes place during the solution; nitrous gas is disengaged because the gold cannot be oxidized unless at the expense of the oxygen of the acid of the nitre.

51. This nitro-muriatic solution of gold, when saturated, is of a fine pure yellow colour, so deep and rich that it is compared to that of gold without brilliancy; it is very caustic and very astringent; it produces upon the cuticle, by cauterizing or destroying it, a spot of a violet-purple colour, which becomes more and more brown by the contact of the air and the light, and does not disappear except by the destruction and total falling off of that membrane; it produces the same colour upon all the vegetable and animal matters, upon marble and even upon the siliceous stones, when, after having introduced it into grooves cut in them with a steel instrument, we expose them to the rays of the sun. By

evaporating this liquor, nitric acid is disengaged, and needled crystals are obtained of a yellow colour resembling that of the topaz, in truncated octahedrons or quadrangular prisms. But it is well ascertained that the solution made with the two acids pure and without bases furnishes them also. We obtain them with greater facility when after having evaporated the solution more than one half, we add a little rectified alcohol: these crystals acquire a red colour by the contact of a bright light; they attract the humidity of the air and melt spontaneously. The product of this deliquescence is the most concentrated solution. When the nitro-muriatic solution of gold is heated by degrees in a retort, there passes, after the nitric acid, muriatic acid which carries over gold, and even reddish-yellow crystals of muriate of gold; the highly coloured nitro-muriatic liquor which rises at the same time was called *Red Lion* by the alchemists. By evaporating the solution to dryness, a dry muriate of gold is obtained, which may be reduced by a strong fire, and leaves ductile gold after having afforded oxygen gas. It has been well ascertained by Bergman and several other modern chemists, that the salt extracted from this liquor is only muriate of gold, not nitro-muriate as had been believed. I have already remarked that the muriatic acid decomposes the nitrate of gold: it is easy to conceive that we ought equally to form a muriate of gold by heating this metal
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with a mixture of alum, and especially of sulphate of iron, of nitre and of marine salt: accordingly this mixture, or others analogous to it, are frequently employed for taking off the gold from the surface of old gilt copper.

52. The muriate of gold, so distinguishable by its form, its colour, the purple tinge which it imparts to the organic matters, is very soluble in water. Phosphorus decomposes it in the humid way, and separates the gold from it in a reduced state. Hydrogen gas equally separates the gold from it. If we immerse into its saturated solution a stick of phosphorus, it becomes covered with a ductile cylinder of gold which may be separated from it by melting the phosphorus which it envelops in hot water. Burning sulphur and sulphureous acid decompose it very rapidly. If we pour liquid muriate of gold gently into sulphureous acid, a fine pellicle of gold is formed at its surface, and gold is immediately precipitated in small crystalline grains. Mrs. Fulham, an English lady, has employed these precipitations of gold by phosphorus, hydrogen gas, and burning sulphur to gild stuffs impregnated with the nitro-muriatic solution of this metal. She has also applied it to form gilt traces upon geographical charts, and has produced a kind of gilding which may be useful in a variety of cases. She has remarked, that this precipitation does not take place in the solution of gold, nor in those of silver and lead, unless they be in the liquid state: and that it is not equally effected with

the solid metallic salts. Mrs. Fulhame has not been equally happy in the explanation of this fact to raise a theory, which is, in reality, useless and superfluous, as to the necessity of the water with regard to a pretended decomposition of that liquid. This theory was not necessary, because it is very easy to conceive the influence of this condition of liquidity in the metallic salts, to divide them by presenting more surface and to fix the reducing gases between their particles. The hydrogen phosphoreous and sulphureous gases produce the same effects on the solution of muriate of gold. The alkaline sulphurets and hidro-sulphurets precipitate it in the form of a sulphurated oxide of gold, easy to be decomposed by heat, on account of the slight adherence of the sulphur and the oxygen to the gold.

53. All the earthy and alkaline substances possess the property of decomposing the muriate of gold, and precipitating from it a yellow oxide of gold, which is the extreme of the oxidation of this metal, since it contains nearly 0,10 of oxygen. It is observed, however, the fixed alkalis precipitate it slowly, and with difficulty: and that, if a greater quantity than is necessary be employed, the precipitate is redissolved, and imparts a reddish colour to the liquor. This solution of oxide of gold by the fixed alkalis, is the reason that the precipitation is slow and difficult: triple salts are formed, which have not yet been examined. The oxide
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of gold thus precipitated becomes purple by exposure to light. By the action of caloric it is reduced to very pure gold, giving out oxygen gas. The sulphuric, nitric, muriatic, sulphureous, phosphoric, and fluoric acids dissolve it, or unite with it easily, while they do not act on the purple oxide: which proves, that the oxidation of gold into a yellow powder imparts to it much more oxygen, than its oxidation into a violet or purple powder, and that the first oxide alone is soluble in acids, while the purple oxide cannot combine with them.

54. The most remarkable precipitation of gold, is that which is effected by ammonia. This produces the singular compound which has been called *fulminating gold*, which was discovered long before the ammoniacal oxide of silver; but its real nature, and the cause of its fulminating property, remained unknown, till Citizen Berthollet made public the latter analogous compound, which differs from it only in possessing much greater power. There is no chemical product that has been examined so much as this. A satisfactory notion may be formed of the numerous researches made by different chemists respecting this compound, from a perusal of the treatise on gold, given in the first volume of Wackerberg's Chemical Institutes, published at Vienna in 1778. In this will be found a very complete, very long, and very well written account of the experiments that were known at the period when
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that learned chemist wrote. The very length of this treatise shows, however, that the knowledge of fulminating gold was not then complete; while the advanced state of the science, in consequence of the pneumatic doctrines, though it requires much less detail, exhibits a much more satisfactory theory, and much more accurate ideas of this compound. A few lines here will supply the place of several pages of Wafferberg's treatise, and will fill up the numerous deficiencies left in that part of his work, so interesting and useful as it notwithstanding is to those, who would wish to have a thorough acquaintance with all the particulars, and all the periods of the history of chemistry. The precision I am enabled here to employ, and which will nevertheless exhibit more numerous facts than those that Wafferberg has laboriously accumulated in his long article, is a strong proof of the advantage of the pneumatic system, and of the height to which the science has been carried by the labours of Frenchmen.

55. To prepare fulminating gold, or ammoniacal oxide of gold, a nitro-muriatic solution of gold is diluted with three or four times its weight of distilled water. Into this caustic ammonia is gradually poured, till it no longer precipitates any thing; care being taken to add no more than is necessary, as the excess will readily dissolve the oxide suspended in the liquor. The precipitate being carefully washed, and dried on paper in the open air, is to be put
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into bottles stopped with a piece of linen, or simply covered with paper. This precipitate is of a red-yellow colour. It weighs about one-fourth more than the gold that was dissolved: some authors say, that in it the weight of the gold is augmented one third. The increase of weight does not depend solely on the saline substances, which accompany it in its precipitation, but likewise on the oxygen, which is united with the gold. This fulminating precipitate may be obtained also by decomposing a solution of gold in the mixed acid composed of the nitric and muriatic by means of a fixed alkali; for this alkali begins with separating ammonia, which attacks the muriate of gold. In short, as often as there is ammonia in the solution, in whatever mode it may have been placed there, the inflammable and detonating substance will be obtained, when the solution is decomposed by any alkaline substance whatever. This general fact is deducible from the experiments of Bergman, related in his *Dissertation de Calce Auri fulminante*. Basil Valentin, who first described this singular preparation, had already remarked, that it was made to detonate equally by heat, by friction, and by percussion. In all cases the sound produced is much louder than that of gunpowder, or that of the pulvis fulminans. Lewis compared the sound of fulminating gold to the vibration of a short cord stretched tight, and that of gunpowder to the sound of a longer and flacker cord.

56. Many unfortunate instances, collected in the memoirs of academies and periodical publications, prove, that fulminating gold detonates by simple pressure, or by friction. We have an irrefragable proof of this in the dreadful accident that happened at Citizen Baumé's, by a dram of fulminating gold, which detonated in consequence of some of its particles being rubbed between the neck of the phial containing it, and the glass stopper; and part of which only, that took fire, burst the bottle with a violent explosion, and with the fragments put out both the eyes of the unfortunate person who was so imprudent as to occasion the friction. We may convince ourselves of it likewise, by putting a little of this powder on a piece of steel, and striking it with a hammer: when a small flame will be visible at the instant the detonation is heard, and the gold will be found reduced on the steel. On carefully examining aurum fulminans, exposed to the fire in a very small quantity on a plate of iron or silver, we perceive it acquire a brown colour: presently a light is seen, at the instant when the gold fulminates, and a trace of very pure gold, without polish, remains on the plate. On detonating a little of this production in a large glass jar, to the side of which it has been applied, by putting a burning coal near the place, the jar will be found covered with little stars of gold after the explosion. Plates of metal placed over it when it detonates are indented or perforated

rated in the part it strikes : they are likewise thrown to a considerable distance, and it is easy thereby to prove, that the fulminating gold strikes the air in all directions. The electric discharge also occasions the detonation of fulminating gold,

57. Bergman has proved, that on exposing aurum fulminans to a very gentle heat, not only no detonation is produced, but it is deprived of its fulminating property. In this case it is changed into a blackish-brown powder. The same thing is effected by long exposure to the heat of boiling water, or rather its fulminating property is thus diminished merely, for it is never entirely taken away by this process. Hellot has observed, that on placing fulminating gold between two cards, and heating it, it gave but a slight report; and left a violet oxide on the cards. When fulminating gold is thrown in little parcels on burning coals, it scintillates only, and decrepitates without fulminating. The contact of air manifestly favours its fulmination : and when an insuperable resistance is opposed to the extrication of the gas accompanying this fulmination in a vessel of sufficient strength and well closed, it does not take place. Thus Birch showed before the Royal Society of London, that fulminating gold enclosed in a globe of iron, and heated strongly, did not fulminate. Bergman verified this fact, and observed, that gold heated in a globe of thick copper, closed by a screw,

was

was reduced without fulminating. He adds, that twelve grains of aurum fulminans, thus treated, yielded a gas, which escaped with a hissing noise, but without detonation. Citizen Berthollet, by gently heating the fulminating precipitate of gold in copper tubes, the extremity of which passed under a jar filled with mercury, obtained ammoniac gas, and the gold was reduced to a violet oxide. Thus it is proved, that a gentle heat, capable of volatilizing the ammonia, and a powerful resistance, sufficient to oppose, even during the application of a strong heat, the sudden dilatation of the gases that are evolved by fulminating gold, equally prevent the fulmination: in the first case ammonia is extricated, and oxide of gold remains; in the second gold is reduced, though no detonation takes place.

58. Before the accurate experiments of Bergman, and particularly before those of Citizen Berthollet, the true cause of the fulmination of this precipitate of gold was unknown. It was conjectured by the first of these chemists, and afterwards placed beyond the reach of doubt by the second. On detonating a few grains of fulminating gold, by means of a powerful heat, in tubes of copper, the extremity of which passed under a jar filled with mercury, Citizen Berthollet obtained azote gas, a few drops of water, and gold thoroughly reduced. The fulminating gold, composed of oxide of gold and ammonia, undergoes therefore a double decomposition

decomposition in the two binary compounds of which it is formed; the hydrogen of the ammonia attacks the oxygen of the oxide of gold, and it is to the dilatation of these two substances, equally violent and sudden, as well as to their rapid condensation the instant they unite to form water, that the flame and report produced during the decomposition are owing. The other principle of the ammonia, azote, become free, is then extricated in the state of an elastic fluid, and thus contributes to the percussion of the air, and the fulmination; while the gold, deprived of its oxygen, re-appears in its metallic form and brilliancy. Fulminating gold then, like fulminating silver, is an ammoniacal oxide. The differences that exist between these two productions certainly depend on the proportions of the oxide and the ammonia which they contain, and on their more or less condensed state; and to have a perfect knowledge of them nothing more remains, than simply to discover these differences of proportion, which render the first much more fulminating than the second.

59. This simple theory of the nature and properties of the fulminating ammoniacal oxide of gold, easily explains the different means which have been employed to destroy its fulminating property. A very gentle heat produces this effect by volatilizing the ammonia, and reducing the compound to the state of simple oxide. A very powerful resistance to the development of
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its principles in the gaseous state, opposes its detonation. Long boiling in water does not answer this purpose, notwithstanding the assertion of some chemists, as is positively proved by the experiments of Bergman, who boiled fulminating gold in six hundred parts of water, twice following, and for an hour each time; but its fulminating property, far from being diminished, was increased by this operation. This proves, that the compound is by no means soluble in water, and only yields to it the foreign and saline matters mixed with it, which are more or less detrimental to its fulminating property. On the contrary, any dry substance interposed between the particles of fulminating gold, prevents it from detonating, or diminishes its fulmination, by separating its particles. It is not true, as many chemists have asserted, that acids in general have the property of destroying its fulminating quality; for Bergman has found, that notwithstanding digestion in them, fulminating gold retains its characteristic property; and particularly, that, if intirely dissolved in muriatic acid, and precipitated from it by potash, it recovered it as before. We may succeed in divesting it of this property, however, if we digest it in acids several times successively, and wash it each time with a large quantity of water. By these means several acids even reduce it to a purple oxide, or to metallic gold. Alkalis mixed with it by a light and gentle trituration singularly diminish its detonating quality.

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If they be digested with water on fulminating gold, they take from it this quality intirely; but the action of a slow heat contributes much to this effect. But all these experiments must be made with caution and the products must afterward be tried in very small quantities. Sulphur, and even oils, have the power of depriving gold of its fulminating property; and it is obvious, that this is owing to their separating from it the ammonia and reducing the oxide, as in the experiments first quoted: accordingly the gold then resumes its metallic form.

60. The muriate of gold, or the solution of gold, which I have proved to be in fact nothing but this species of salt, is decomposed by most of the metallic substances, which have a stronger affinity for oxygen than gold has. Bismuth, zinc, iron, lead, copper, silver, and even mercury, have especially this property; it is occasionally employed with advantage to cover some of these metals with a coat of gold: others of them, however, as lead and silver, separate it only in the state of purple oxide. It is on the principle of the first of these phenomena, the reduction and precipitation of gold reduced by metals, that the brass wheels used in watch-work are gilt. But no one of these precipitations is so singular, or has more engaged the attention of chemists, than that which is effected by tin. In this again we shall find a proof of the advantage of the pneumatic system, which

alone has been sufficient to remove all the difficulties, whether practical or theoretical, with which this chemical operation was beset: besides, in the explanation respecting it, this system dispenses with all the details, which were formerly necessary to be given, concerning the preparation afforded by the precipitation of gold effected by means of tin. Cassius was the first who described this preparation with care, though it was known before his time, and mentioned in several chemical works, particularly in those of Basil Valentin. Erxleben has given a very minute dissertation on this subject; but, notwithstanding the numerous and useful experiments with which it abounds, the subject was far from being properly elucidated, before Pelletier's experiments on the two states of the muriatic solution of tin, which has dissipated all the obscurities in which this process was still involved.

61. When a plate of tin is put into a solution of gold, the surface of the metal is at once tinged with a very deep purple or violet, and a powder of this colour, of extreme tenuity, gradually diffuses itself throughout the fluid, destroying its transparency, and rendering it almost black. This powder is called *the precipitate of Cassius, purple precipitate, or mineral purple*. It is not by this process that it is prepared in large quantities for the manufacture of porcelain and earthen-ware, in which it is much used, but by mixing a solution of tin in nitromuriatic

muriatic or muriatic acid with the solution of gold, in which way it is obtained in abundance. Formerly, however, this mixture did not always afford the required colour: sometimes it yielded only a dirty brown, and sometimes nothing was produced by the mixture. Though some observations, made by several chemists, might have led to the discovery of the true cause of all these uncertainties, it was not clearly known till Pelletier found that the muriate of tin possessed the property of absorbing oxygen from the atmosphere; that when saturated with it, it no longer afforded purple precipitate; that this precipitate even depended on the great avidity of tin for oxygen, when not saturated with this principle; that it took it from the yellow oxide of gold, and that, in bringing it back to the state of purple oxide, it separated it from its solution, in which it united with it intimately; that for this reason the fuming liquor of Libavius, or super-oxygenated muriate of tin, does not precipitate the solution of gold; that on the same account a solution of tin, long made, and exposed to the air from which it had absorbed oxygen so as to saturate itself, no longer yielded purple precipitate with the muriate of gold; that a solution, which had yet absorbed but a small portion of oxygen, formed with it a pale red or fawn-coloured precipitate; and that this precipitate consisting in the difoxidation of gold by tin, and in the union of the oxide of gold, partly difoxidized
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with the oxide of tin, more oxygenated than before, it will henceforward be always easy to prepare the purple precipitate at pleasure, and this important preparation will no longer be liable to failure. The experience of all chemists confirms this simple and perspicuous theory of Pelletier.

62. It is to the same principle, to the great attraction of iron for oxygen, when not saturated with it, that the decomposition of the muriatic solution of gold is owing, on pouring into it a solution of fresh green sulphate of iron, which instantly occasions a precipitate of reduced gold. Bergman thought this precipitate approached so near to the state of gold, that he gives this as a method of discovering and ascertaining the proportion of this metal dissolved in assaying ores in the humid way. Red, or super-oxygenated sulphate of iron, does not form a similar precipitate in the muriate of gold.

63. Several other metallic solutions have equally the property of decomposing and precipitating the muriatic solution of gold. The nitrate of silver forms in it a reddish precipitate, which is a mixture of white muriate of silver and purple oxide of gold. That of lead yields a dusky and dark precipitate, composed of oxide of gold and muriate of lead. We are very far from knowing all the reciprocal effects, which the different metallic salts are capable of producing, and the compounds
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they form with the solution of gold, on which many of them have the faculty of acting.

64. The metallic acids do not attack gold, or in any degree alter its qualities. Citizen Vauquelin, in his researches and discoveries respecting the chromic acid, has found, that this acid, mixed with the muriatic, imparted to it the property of dissolving gold. This is owing to the chromic acid permitting the muriatic to take from it part of its oxygen, as he found it did by direct experiments; and as the transference of the chromic acid from its natural orange colour to the state of green oxide, in proportion as the action on the gold takes place, proved to him beyond contradiction.

1. Action on the Bases and on the Salts.

65. GOLD, in the metallic state, has no affinity for earths and alkalis, from which it undergoes no alteration. In the state of purple oxide, and still better in that of yellow oxide, it unites with earths vitrified by alkalis, and forms violet or purple enamels, or gold-coloured glasses. It is in consequence of the latter property, that it is employed in the fabrication of artificial topazes. These glasses, coloured yellow by gold, into the composition of which a large portion of the oxide of lead enters, and often that of manganese, sometimes exhibit a very remarkable property. This is on being gently heated, and long before they melt, they

acquire a permanent purple colour, or a ruby red; which is apparently owing to an alteration in the equilibrium and combination of the oxygen.

56. No purple oxide of gold, by whatever process made, experiences any change from alkalis or ammonia; but its yellow oxide, precipitated from its solution by fixed alkalis, being digested for some time with ammonia, readily passes to the state of fulminating gold; which is essential to be known by operators on this metal, that they may not expose themselves, in their various operations with gold, to convert it unawares into the state of ammoniacal oxides, which would fulminate when attempted to be reduced by means of heat.

67. The most active salts, the nitrates and the super-oxygenated muriates, have no action on pure gold. Yet it has been observed, that borax renders its colour paler, and that nitre, which is sometimes employed to purify and refine it, as well as to collect together the different particles of this metal, heightens its colour, and renders it much more brilliant than it would have been without this addition.

K. *Uses.*

68. BESIDE the real price affixed to gold on account of its beauty, unalterableness, and scarcity; beside that of opinion and prejudice, which human passions have given to it, and
which

which makes it considered as the first and most useful in nature; it has of itself, and in consequence of its peculiar qualities, a number of useful properties, which alone are sufficient to render it worthy the rank it holds in the minds and estimation of mankind. Its scarcity does not permit it to be made into utensils itself: those of small bulk, which are fabricated with it, cannot be wrought of the pure metal, which is too soft to preserve sufficiently the figure that might be given to it. In general it is alloyed with a tenth or twelfth of its weight of copper, which imparts to it the consistence and hardness requisite; and this constitutes the gold of twenty-two carats in trade, or for jewellery. Gold coins which are smaller, thicker, and of a more solid form than that of trinkets, contain only a twenty-fourth of alloy, and are of twenty-three (in England twenty-two) carats.

69. The brilliancy and fine colour of gold, added to its indestructibility, are too pleasing to the eye, and excite too striking a sentiment of gaiety and pleasure, not to have led men long ago to seek the art, and consequently much to improve it, of extending its appearance, of reducing it almost wholly to surface, and of covering with it a number of substances, which it adorns, enriches, and at the same time defends from every kind of alteration and destruction. Hence, the numerous kinds and varieties of gildings or applications of gold on iron, copper, silver, and other metals, on stones

and insoluble salts, on wood and stuffs, on paper and pasteboard. The slightest or most superficial gildings are made with solutions of gold, which are reduced either by a metallic surface, or by phosphorus, burning sulphur, and sulphureous acid, as in the ingenious processes of Mrs. Fulham. Some of the most simple consist in applying by means of a mordant, or a glutinous mixture capable of desiccation, leaves of gold, the successive layers of which are more or fewer, which are rendered very smooth by the friction and pressure of hard bodies, and which are made to enter into every cavity, and adapt themselves exactly to every figure, without breaking, by means of small instruments, which press them nicely into every hollow. Such is the gilding on wood, pasteboard, tortoiseshell, horn, bone, stones, and a number of substances not of a metallic nature.

70. What is called *shell-gold*, which is frequently employed for certain gildings, is prepared by triturating fragments of leaf gold with honey, washing them with water, and afterwards drying the particles of gold that subside. *Gold calx* is gold in purple oxide, precipitated from its solution, and diluted with a mucilaginous water, or a solution of gum. To make *rag-gold*, which is likewise used for some species of gildings, fine old linen rags are dipped in a nitro-muriatic solution of gold, dried, and then burned. When they are used, a wet cork is dipped in the ashes of these rags, and this rubbed

rubbed on silver, to which the gold in a very attenuated state readily adheres. Sometimes in the gildings in which gold is applied in a brown oxide, the pieces are passed slightly through the fire, to restore to the metal its purity and brilliancy. The vapour of sulphur, or sulphureous acid, might be employed for the same purpose.

71. Gilding in *or moulu*, or water gilding, is the most valuable, and most solid. It is most frequently applied on copper or brass. The metal to be gilt is first well cleaned by means of sand, and diluted nitric acid, which is called *aqua secunda*. It is dipped into this liquor, and rubbed with a brush of brass wire, of the shape of those used by painters, and called a *scratch-brush*. It is next put into a nitric solution of quick-silver very much diluted with water, which deposits on the copper a slight layer of metallic quick-silver. The intention of this is to cause the amalgam of gold, which is spread over the metal (previously washed in a large quantity of water to carry off the acid), to acquire a strong adhesion to it. When the amalgam is spread very uniformly over the metal, it is heated, by placing it over a fire, to volatilize all the mercury. The gold remains alone, and of a dull yellow colour. A brilliancy and polish are imparted to it by rubbing it with what is called *gilding-wax*, or a mixture of red bole (ferruginous argil), verdigris, alum, and sulphate
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of iron, incorporated with yellow wax, and afterward heating the work a second time, to burn the wax.

72. The application of gold on silver, a species of gilding in or moulu known by the name of *vermeil*, succeeds still better, and takes a much richer colour, as well as greater solidity, by means of the amalgam, which is simply applied on the silver well cleaned by nitric acid. The silver is then heated in an open fire to expel the mercury. Different tints or shades of yellow, red, purple, or a greenish colour, are given to these valuable and durable gildings by different saline or other matters, which are applied to them in powder, or in a paste, and heated on the amalgam. They are burnished in the usual manner by friction and pressure with hard and polished bodies. Silver gilt, or *vermeil*, perfectly resembles gold in colour.

73. Two of the most industrious and interesting of the arts employed on gold are those of the gold-beater and wire-drawer. These are founded on the extreme ductility of this metal, and the facility with which it may be extended. Gold-beating consists in striking the metal, with a regular and sure stroke, between pieces of the membrane, called gold-beater's skin, on a steel anvil perfectly even, with square hammers, equally smooth and well finished. By repeated strokes the gold is reduced to leaves so thin as to be carried away by the wind. These are then cut into squares, and placed between leaves of soft paper,

paper, which is impregnated with red bole in its body. This makes what are called books. The gold leaves are perforated with thousands of holes, so that the light may be seen through them, if held between it and the eye: but, notwithstanding these numerous breaks, their cohesion is still sufficiently great, to hold them together in one piece, so that they may be applied whole on the surface of many other bodies. The art of the gold wire-drawer is not less remarkable. A cylinder of silver, covered with a layer of gold, or solidly gilt, is passed and drawn by force through holes made in a piece of steel, from those which are nearly of the diameter of the first cylinder, or differing from it but a little, to those which give almost imperceptible threads, and is constantly elongated in the same state, forming a solid cylinder of silver covered with a coating of gold, the thinness of which seems to defy the imagination. These gold leaves, and these slender threads of silver gilt, which are commonly called *gold wire*, serve for a great many uses, in the numerous arts in which they are employed.

74. Among the various employments with which gold furnishes to men, the art displayed by the goldsmith and jeweller in giving its plates, its little cylinders, or its wires, all those various and elegant forms in which we see it, is not the least deserving praise. Vessels, utensils, jewels, and trinkets of gold, the fruits of the industry,

industry, talents, skill, ability, and invention of these intelligent workmen, are continually enhancing its price an hundred fold; and these articles, in which taste, and the improvement of the fine art of design display themselves in a superior manner year after year, while they supply perpetual food for that luxury, which is happily insatiable, are the beneficial occasion of furnishing many hands with employment, and of promoting among modern nations that commerce, which multiplies the enjoyments of man, and is the source of wealth and prosperity to so many countries. It belongs to the nature and perfectibility of man, to be pleased with trinkets and utensils of gold, since the savage both of Africa and America, who has so few wants in other respects when compared with the delicate cities of Europe, loads the ears, the arms, the fingers, the nostrils, and even the lips of his spouse with bits of the grains and filaments of gold which he collects in rivulets and streams, and which he bends or works with ease, in consequence of its purity, and the softness of this native metal.

75 Disseminated in thin plates of every shape, or in foils, twisted in curls, drawn out into the form of solid wires, or rolled round threads of silk which support it and add to its bulk and strength, gold is still further employed on the garments of various individuals, in embroidery, tissues, and laces. Sometimes it denotes the opulence and luxury of those by whom

whom it is worn; at others it is used as a decoration, and as a mark of dignities among men. It is interwoven with silk, with linen, with woollen, with hair, with feathers; it is combined with colours of every hue; it is even made to shine through little layers of glass, which soften or moderate its lustre, or project or multiply the brilliant rays reflected by its surface; and it is sufficiently known how much, as an article of dress, it attracts the eye, and seems to command respect and almost obedience. Accordingly, it always makes a part of the ornaments of superior dignity, in the distinction of ranks among people who admit them; and is employed in festivals, public performances and exhibitions, civil and religious ceremonies; in short on every occasion, where it is an object to attract attention, or to produce sentiments of admiration and astonishment, to strike the imagination and fix the eyes of the multitude.

76. Gold is likewise distinguished by the beautiful colours and rich tints, which it communicates to enamels, to paintings on porcelain and earthenware, to coloured glasses, and to imitations of precious stones. Violets, purples, purple-browns, violet or purple-blues, topaz yellows, and the brilliant and lively reds of the ruby and Syrian garnet, are the chief varieties of tint, which the oxides of gold, more or less strongly and rapidly heated, or mixed with earths or fluxes of different natures, and
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in different quantities, produce in all the arts of vitrification.

77. I have already noticed, at the beginning of this article, that it is sometimes employed to preserve iron from rust; and that, notwithstanding all the pretended nobleness of its nature and origin, ascribed to it by the alchemists, it is modestly submitted to the office of the simple preserver or protector of a metal deemed the most common, and almost the basest, that nature has created. It has the same office in the gildings of railing, of some parts of watch-work, and of various philosophical instruments; and at some future period it may be employed still more extensively for this purpose of covering and preserving iron from that great and speedy alterability by which it is distinguished.

78. It is not difficult to conceive, that a metal so valuable and so much prized should likewise be ranked in the number of medicinal substances. To what has not man had recourse, for the purpose of assuaging his pains, curing his diseases, and prolonging his existence? I have already shown above, that cordial, alexipharmic, and other virtues had been ascribed to it, but that these have existed only in the imaginations of those who boasted of them. Accordingly, all the receipts for potable gold are now classed in the list of ridiculous and useless medicines.

ARTICLE XXII.

*Of Platina.**A. History.*

1. PLATINA, which forms the last in the order of metals, the most intractable and indestructible of all, was not known by chemists before the middle of the eighteenth century. Under this name, however, which is of Spanish origin, and signifies *little* or inferior *silver*, some white trinkets of little estimation were sold, before the metal was distinctly known. Antonio de Ulloa, a Spanish mathematician, who accompanied the members of the French academy in their famous voyage to Peru, for the purpose of ascertaining the figure of the earth, first gave something like a precise notion of it, in the account of his voyage published at Madrid in 1748. It is observed, that Mr. Charles Wood, an English metallurgist, brought some of it from Jamaica in 1741. This gentleman related some experiments on this new metal in the Philosophical Transactions for 1749 and 1750.

2. These first experiments, which announced very extraordinary properties, made a great noise in Europe, at a period when the discovery

of a metal, particularly one so singular as this appeared to be, was a phenomenon beyond what any one had dared to hope. The greatest chemists of Europe were then eager to examine platina, and investigate its distinguishing characters. Scheffer, a Swedish chemist, whose lectures were published by Bergman, gave the first accurate series of experiments on this metal in the Memoirs of the Academy of Stockholm, in 1752, in consequence of which he ranked this metal near gold for its properties, and called it *white gold*. Lewis, an English chemist, to whom we are indebted, among other things, for a history of silver and of gold very complete for the time, made a very complete and regular series of experiments on platina, which he published in the Philosophical Transactions for 1754. In the Memoirs of the Academy of Berlin, for 1757, Margraff gave an account of his experiments on this metal. All these early labours were collected and compared by Morin, in a work he published in France in 1758, under the title of *Platina, White Gold, or the eighth Metal*. This is a methodical compilation of all that had been done previous to that period.

3. At this time Macquer and Citizen Baumé undertook in concert a great many interesting experiments on platina, which are recorded in the Memoirs of the Academy of Sciences for 1758. Buffon soon after related in the first volume of his Supplement a series of researches, which he made

made in conjunction with Milly and Citizen Guyton. Mr. Von Sickingen too made many useful experiments on platina, which he communicated to the academy, and of which Macquer has given a minute abstract in his Chemical Dictionary. De Lisle, also, nearly at the same time, presented the Academy of Sciences with his labours on this metal.

4. After these researches, already very numerous, Achard, Citizen Guyton, Lavoisier, and Pelletier, successively published methods of obtaining platina pure, and of fusing it, and new information respecting its combinations. Bergman has written a particular dissertation on the nature of its precipitates produced by different alkaline re-agents. Mr. Chabanon, at that time professor of chemistry in Spain, busied himself in processes for treating this metal in the large way, in which he succeeded. In Paris likewise, skilful artists applied with ardour to this object. Citizens Carrochez, an engineer, and Jeannety, a goldsmith, both found out useful processes for purifying platina, and forging it. The first has constructed mirrors for telescopes of it; and the second is daily fabricating of it thin plates, wires, crucibles, and all kinds of utensils employed in chemistry and natural philosophy.

5. From these different labours combined, we have acquired a considerable knowledge of the properties of platina, though there are still many things desirable for completing the
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the history of this metal. The pneumatic system has done nothing with regard to platina, except teaching us to place it on a level with gold in respect to its difficult oxidability, its little affinity for oxygen, and its consequent inalterability by the majority of other substances.

B. Physical Properties.

6. Platina, purified by the processes which will presently be mentioned, is of a less beautiful white than silver, and verging a little towards the grey colour of iron. When burnished it has a blackish tint, and not the white lustre of silver. Its unpolished parts are somewhat grey and dull. Its appearance is not so brilliant and pleasing as that of silver, or gold; and most men, though likely to confound it with other metals, would not form from the sight of it the same idea as of those two precious metals, which attract their eyes and excite their admiration, or attach to it the same value.

7. This metal is the most dense and heavy of all natural substances. When it is slightly hammered or forged, its specific gravity is to that of water as 20,850 : 1,000; when it is strongly laminated, it reaches to 20,980, according to the experiments of Citizen Borda. Sickingen carries it to 21,061, and Mr. Chabanon to 24,000. Its hardness is not the greatest observable among metals: in respect to this property Citizen Guyton

Guyton assigns it the third rank among them, after iron and manganese, and before copper.

8. The elasticity of platina appears to be pretty considerable. Its ductility is great; though it is far from being easily wrought, it is reduced to very slender wires, and very thin leaves. Citizen Guyton gives it the second rank in this respect, placing it between gold and silver. It is easily bended: and the resistance and cohesion of its molecules in the plates fabricated of it, will, at some future period, admit a great number of uses to be made of it of high importance. Citizen Guyton has made the last and most accurate experiments on its tenacity, or the cohesion of its particles. In this point he assigns it the third rank, after iron and copper, and before silver and gold. He has found, that wires of these five metals, drawn through the same, and two millimetres in diameter, sustained the following weights without breaking.

Iron	-	249,659 kilogrammes
Copper	-	137,399
Platina	-	124,690
Silver	-	85,062
Gold	-	68,216

9. Platina, like all other metals, heats quickly, and is a very good conductor of caloric. Citizen Borda has found, that its dilatation is $\frac{1}{11000}$ to a degree of Reaumur's, and $\frac{1}{116000}$ to a degree of the decimal thermometer. Of all metals it is the most intractable in the fire,

fire, and the most difficult to fuse. It goes beyond iron and manganese in this property. Citizen Guyton estimates its fusibility at $160+x$: that is to say, at a degree yet unknown, or beyond the utmost limit of Wedgwood's pyrometer: while, as has been seen elsewhere, he places that of manganese at 160, and that of iron at 130. In fact, the greatest fire known in our furnaces scarcely soften, perceptibly, the platina in grains. At the most extreme degrees of heat, we can only agglutinate these grains together, without imparting to them a true or strong adhesion, since they may be separated by hammering. Macquer and Citizen Baumé kept several, in a continued line, exposed to the constant and violent heat of a glass-house furnace; and these grains only stuck slightly to each other, for they were afterwards separated by the hand. They perceived their colour become very brilliant, when they were of a white heat. On exposing these same grains of platina, well purified, to the focus of the burning lens of the Academy, the portions placed in the centre of the focus smoked, melted at the end of a minute, and formed an homogeneous button, white and brilliant, very ductile and capable of being cut with a knife. Citizen Guyton likewise succeeded in fusing small portions in a crucible, by the help of his reducing flux, composed of eight parts of pounded glass, one of calcined borax, and half a part of charcoal, and employing for this operation

ration Macquer's wind-furnace. Lavoisier also fused small portions of platina in a cavity on charcoal with a blast of oxygen gas. After all these trials there is nothing more easy than to procure little buttons of this metal thus melted; but they are in such small masses, that it is impossible to employ them in decisive experiments; and we may still say, that no real and useful fusion of platina has been obtained; since, when treated by the ordinary means, it is impossible to fuse it in such a quantity as allows us well to examine its properties, and employ it in experiments capable of rendering us acquainted with them. Accordingly it will appear further on, that, to apply it to the uses already made of it, the fabrication of plates, bars, wires, vessels, &c. it has been necessary to fuse it by the help of some alloys, and separate it afterwards by forging from the metals united with it. Of this I shall speak under the article metallurgy.

10. Platina is a very good conductor of the electric fluid and of galvanism. Its power in this respect has not been compared with that of other metals, but it appears to be very great. It has neither smell nor taste, in which it resembles silver and gold.

C. Natural History.

11. PLATINA has hitherto been found nowhere, except in the gold mines of America, particularly in that of Santa Fè, near Carthagena, and in the

bailiwick of Choco, in Peru. It is collected in the form of little grains, of a livid grey or white, the colour of which partakes of those of silver and iron. These grains are mixed with several foreign substances: among them are found gold dust, blackish ferruginous sand, grains that appear through the lens scorified like the slag of iron, and some particles of mercury.

12. On examining the grains of platina with a lens, some appear angular, and others rounded or flattened like some pebbles. They may be flattened under the hammer: but some fly to pieces; and these frequently appear hollow within, and contain portions of iron and a white powder. To these small grains of iron must be ascribed the property of being attracted by the magnet, observed in the grains of platina, though well separated from the ferruginous sand among them. To obtain the purest and largest grains of platina, they are sorted by hand, and the gold dust, quartz, sand, and iron are separated from them.

It is probable that platina is not found in the earth, as it is brought to us, and as it is seen in mineralogical collections. The form of grains which it exhibits, is owing either to the motion of the water by which it is carried down from the mountains into the plains, or to the grinding of the mills, through which the ores of gold, with which it is mingled in the native state, are passed. Sometimes pretty

large

large pieces of it have been found. The Society of Biscay has in its collection a piece as large as a pigeon's egg. These separate pieces, so much larger than the rest, frequently resemble an egg in shape. Citizen Gillet has one of this figure, about a centimetre, or four lines and a half long, seven millimetres, or three lines and $\frac{1}{4}$ in its greatest breadth, and weighing nearly 21 decigrammes, or 40 grains. No naturalist has yet described the situations, gangues, or varieties of ores of platina. It is at present the least known of all metals; and perhaps the only one, which, being found hitherto only in one state, been likewise discovered but in one single country.

D. *Affay and Metallurgy.*

14. PLATINA is very distinguishable by its form, colour, and specific gravity. As it is always mixed with sand and iron, and frequently with gold and quick-silver, beside the sorting by hand already mentioned, by means of which Tillet found some grains of this metal embedded in a quartz gangue, different processes are employed for its purification. It is heated red-hot to volatilize the portion of mercury left by the amalgamation, by means of which gold was obtained from it. Iron is separated from it by the magnet, which frequently takes up with this attractable metal little fragments of platina. The grains are also heated with muriatic acid,

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which

which dissolves and takes up the iron. Bergman has remarked, that platina loses 0,05 of its weight by this operation. After this nothing remains but the platina and the gold, both of which are to be dissolved in nitro-muriatic acid; and the proportions of the two metals may be found by precipitating the gold by fulphate of iron, and carefully weighing the precipitate, which, as I have said, is in a metallic powder.

15. As to operations in the great, there is no one yet settled or practised. The Spanish government having found that its miners debased gold with platina, and that it was difficult to discover the fraud, on account of the specific gravity and unalterableness of this compound, is said to have shut up the mines of platina; but this is an improper expression, which requires to be explained so as to leave no ambiguity or uncertainty. It appears, that platina being always found mixed with gold ore, and both being disseminated in the native state, in the same gangue, it is impossible that the mines of platina can have been shut: but as fast as this metal, which does not dissolve like gold in quick-silver, is extracted and separated, it is thrown away or set apart, so that it is no longer met with in trade as formerly. Hence it is, that the mode of treating it in the large way has made no progress, and that no work in this new branch of metallurgy, has hitherto been erected.

16. Accord-

16. Accordingly, what belongs to the metallurgy of platina, is nothing more than a series of operations on a larger scale than those of a simple assay, though on a much less than the usual metallurgic operations. It is by these, that Citizens Carrochez, Jeannety, Chabanon, and several others, have accomplished the fusion, particularly by the help of arsenious acid, or what is called white arsenic, of some considerable quantities of platina, such as a few kilogrammes; they have hammered and forged it by repeatedly heating and softening it, so as to deprive it by little and little, and at length completely, of the arsenic which rendered it fusible, and preserved its continuous and connected form, so as to admit of its being flattened, fashioned on moulds, and drawn into wire. It is by a similar operation that it has been brought to the greatest purity, reduced to the common state of other metals, and made to assume forms, which may render it useful for various purposes.

As the different processes, employed by most of the artists abovementioned for purifying, fusing, and forging platina in the large way, have not yet been described, I conceive it may not be useless to present the reader with that of Citizen Jeannety, published by himself in the Report made by Pelletier to the *Bureau de Consultation*, in 1790.

Citizen

*Citizen Jeannety's Process for obtaining Platina
in Bars, and Malleable.*

“THE platina must be pounded to free it from the ferruginous and heterogeneous substances mixed with it. This preliminary operation being performed, I take three marks of platina, six marks of white arsenic in powder, and two marks of purified pot-ash, and mix the whole together. On the fire I place a crucible that will hold forty marks, and when my furnace and my crucible are very hot, I throw into the crucible one third of the mixture, and give it a good heat. After this I throw in a second charge, and so again a third, taking care at each charge to mix the whole with a red of platina. I then give a good force to the fire; and when I am certain that the whole is completely in a state of fusion, I withdraw my crucible, and leave it to cool. After having broken it, I find a button well formed, which attracts the magnet: I break my button; I fuse it a second time in the same manner; and if this second fusion have not purified it of iron, I fuse it a third time. In general, however, two fusions are sufficient; and if I be forced to employ a third, I put two buttons together, to save a crucible and charcoal.

“This first operation being finished, I take crucibles with flat bottoms, of such a circumference as to give the button about three inches
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and a quarter diameter; I heat these very red; and I throw into each three marks of platina, which has been fused by arsenic, after having broken it, and added to it an equal weight of arsenic, and about a mark of purified pot-ash. I then give a good force to the fire; and after I am certain that the whole is in a state of complete fusion, I withdraw my crucible, and set it to cool, taking care to place it horizontally, that my buttons may be of an uniform thickness. After having broken the crucible, I find a very clear and sonorous button, commonly weighing three marks three ounces. I have observed, that the more arsenic was combined with the platina, the more readily and easily this was purified. In this state I put my button into a furnace under a muffle, which ought not to be higher than the circumference of the buttons placed edgewise, and inclining a little toward the sides of the muffle. I place in this manner three on each side of the muffle: I apply fire to my furnace, so that the muffle may be heated uniformly throughout its circumference; and the moment the buttons begin to smoke I shut the doors of my furnace to keep the heat at the same degree. This ought to be attended to till the operation is finished; for a single excess of too violent heat would frustrate all the pains before taken. I expose my buttons to this evaporation for six hours, taking care to change their places, that they may all receive the same degree of heat, and I put them into common oil. I keep them an equal length of time in a
fire

fire sufficient to dissipate the oil in vapour. I continue this operation as long as any thing continues to evaporate from the button; and when the evaporation ceases, I urge the fire as far as is possible by means of the oil. The arsenical vapours have a metallic brilliancy, which I cannot obtain without the intervention of some substance; and I have never been able to procure platina perfectly malleable without this agent.

“ If these preliminary operations, which I have pointed out, be properly executed, the process continues only eight days. I then cleanse my buttons in nitrous acid; I boil them in distilled water till no acid adheres to them any longer; I then place several of them on one another; I apply to them the strongest degree of heat possible, and I strike them with the coining engine, taking care to heat them the first time in a crucible, that no foreign substance might introduce itself into my buttons, which are only spongy masses before this first compression. Afterward I heat them in the naked fire, and form them into a square, which I beat on every side a longer or shorter time, according to the bulk they have.”

17. There is every reason to believe, that the Spanish government, which possesses the only mines of platina known in America, and which is aware, that chemistry furnishes means of knowing with certainty all the mixtures of platina with silver and gold, in all their proportions, so
that

that there is no longer reason to be under any fears for the security of trade, will soon afford metallurgists an opportunity of improving the modes of working, purifying, fusing, and particularly forging of platina, by bringing this valuable metal into circulation, at no very distant time from the present. There is equal reason to presume, that this operation, pursued on the plan of the first assays, which have already succeeded so well with the artists and men of science whom I have quoted, will soon reduce it to a lower price than they now hold these new productions of industry, narrow and broad plates, ingots and wires of pure platina, the uses of which will be recounted at the end of the present article.

E. Oxidability by the Air.

18. PLATINA is so far from being altered, either in its colour or brilliancy, by long exposure to the air, even with a great increase of temperature, that it seems in this respect to exceed even silver or gold; for an ingot or plate of each of these three metals, well polished and burnished, being heated red hot at the same time, and in the same fire, through which a current of air passed, those of silver and gold underwent a slight alteration in their colour, which became dull and lost its polish, while that of platina, after being taken out of the fire and cooled in the air, retained its polish and lustre:
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this is owing to its much greater density, and the extreme contiguity of its molecules.

19. The same unalterableness, or perfect indestructibility, does not appear to exist altogether in the same degree in the grains of native platina. Macquer has observed, that these grains, strongly heated in a crucible in a glass-house furnace, assumed a dull and deep grey colour on cooling in the air, and were increased in weight. The same observation made before by Margraff, and agreeing with several other analogous facts of the deepening of the colour of this metal, in cases in which it is oxidized, seems to indicate, that, after having been strongly heated, and when kept immersed in air during its refrigeration, it is capable of absorbing a slight portion of oxygen, which it is true indeed never exceeds a few thousandth parts.

20. This phenomenon, seen by every chemist who has described the action of a strong fire combined with that of the contact of air on platina in grains, is no reason why we should not consider it as one of the most unalterable and indestructible, by the atmosphere, of all metals, as one of those which remain in it the most pure, and the largest space of time, without the slightest alteration or loss, when it is left exposed to it in pieces, in bars, in plates, in leaves, or in wire: for, as I cannot too forcibly inculcate, it possesses a greater density, and of course a much greater immutability, in its pure state, and after having been subjected to compression,

pression, than when it is in the form of dust or grains given it by nature. Besides, it must also be remarked, that many of the authors, whom I am obliged to quote, in order to give a complete history of the properties of this metal, have frequently operated on platina in its native state of grains, and consequently ought to have attributed to the iron, of which it contains at least 0,05, the attractions of which they imagined it susceptible: so that there are always some corrections necessary in the account of observations made before the pieces, plates, and wires of pure platina had become more common, as they are at present.

21. In spite of this singular unalterableness of platina, exceeding that of silver or gold, it is still, however, only relative to the feeble means of division and temperature, which we have at our disposal. The late experiment made of oxidation by means of the violent electric shock, for which we are indebted to Citizen Van Marum, have proved, that wire of this metal might be broken to pieces and inflamed in the air, and dispersed in it in a powder resembling smoke, which was a true oxide of platina. On receiving this powder on a piece of paper, or on burning this metal fastened on a piece of white paper, we have, instead of a kind of smoke, a dirty grey spot, which fixes on this substance, and penetrates it so deeply as not to be removable from it. A white, but not very bright flame, is seen during this act of deflagration.

Thus

Thus, at the high temperature, and in the state of extreme division, imparted to it by the electric shock, it takes fire, inflames, and burns, like all other combustible substances. But the effect of this violent combustion cannot be considered as the extreme of the oxidation of platina. It appears, that this powder does not contain all the oxygen it is capable of absorbing; that it is but an incipient oxide, the oxidation of which may be carried farther, as we shall see by the action of acids capable of attacking it. For the rest, this oxide has not yet been collected in quantities sufficient to ascertain its properties, and determine its increase of weight: and it is only from analogy, very strong it must be confessed, that we consider it as easily decomposable, and susceptible of having its oxygen expelled, and being completely reduced by the action of heat.

F. Union with Combustible Substances.

22. PHOSPHORUS, and the greater number of metals, are the only combustible substances capable of combining with platina. All the other substances of this order form no combination with it. Azote, hydrogen, carbon, and sulphur in particular, which unites with so many other metallic substances, have no action on platina, and form no compound with it. This resistance to combination, this feebleness, this absence even of affinity in platina, is evidently

dently owing to the density and contiguity of its own molecules, which adhere too strongly to each other, to be attracted by those of other bodies.

23. Margraff had perceived a marked action between platina and phosphorus; but he had only a glimpse of the combination, which these two substances are capable of forming together; it is to Pelletier that we are indebted for the real and accurate knowledge of their union. A mixture of equal parts of purified platina in grains and the glacial acid of phosphorus, to which he had added an eighth of its weight of charcoal, exposed in a crucible for an hour to the degree of heat that melts gold, yielded him, under a blackish glass, a small button of a silvery white; a little heavier than the platina employed, and the bottom of which was filled with cubic crystals. This button was a real phosphoret of platina, very hard, yielding sparks with the steel, not attracted by the magnet, very brittle, giving out the phosphorus in a fire capable of keeping it in a state of fusion, and becoming covered with a glass, at first black, afterward green, blueish, and white. This successive gradation of colour in the glass induced Pelletier to imagine, that phosphorus was proper for separating the iron from platina, and thus purifying this metal. By exposing this phosphoret to a strong fire in cupels, repeatedly renewed, he accomplished the separation of all the iron by the help of the phosphoric

phoric glass, which carried it with it as it penetrated the earth of the bones. Platina exposed to this sort of cupellation four times successively was in a button capable of being flattened into a plate, but still brittle when hot. By varying this experiment Pelletier succeeded in refining platina, so as to render it very pure. The phosphoret of this metal detonates strongly, when thrown in powder upon nitre in fusion: a mixture of it with super-oxygenated muriate of pot-ash, projected into a red-hot crucible, produces a brisk detonation, and the platina is left very pure at the bottom of the vessel.

Having heated platina in grains red hot in a crucible, he projected phosphorus into it. The metal entered quickly into fusion: a brittle, hard phosphoret was formed, of a close grain, pretty similar to the white of steel, and covered with a coat of black glass: it had acquired a little more than a sixth of its primitive weight. This phosphoret, exposed to a strong fire, loses its phosphorus, which rises to the surface and burns, and leaves the platina infusible in a scorified and porous mass, very malleable, very pure, only retaining a little glacial acid of phosphorus between its molecules. By striking it, after being brought to a white heat, with the press used in coining, he forced out all the glass it contained, and procured a button of platina very pure and very malleable. He employed this process for making scales, and planchets of which he struck medals. He rested
satisfied

satisfied with this mode as one of the best for separating completely the iron, which platina contains, and on which alone the phosphoric acid acts. To effect this important purification, he fused two parts of platina with one of the glacial acid.

24. Though sulphur do not attack platina, yet the alkaline fulphurets dissolve it, and alter its properties. In this respect it comports itself like gold, and passes fluid through filters by the help of this dissolution; which, however, is much less easy and decisive with this metal, than with gold. It cannot be doubted, that a similar result would be obtained with phosphorus and the alkalis; but this kind of combination, which the direct union of phosphorus with platina would render probable, has not been examined.

25. Arsenic unites with platina, and forms with it a hard, stiff, and brittle compound. The action of the arsenious acid, or oxide of arsenic, on platina has engaged much attention. Mr. Achard and Citizen Guyton are the two chemists who first treated this metal with white arsenic, as it was then called, before the appropriate term of arsenious acid was adopted. It was by this very fusing addition that they succeeded in melting and casting this metal, in purifying it from different foreign matters, which it is liable to contain, and of procuring it pure, ductile, and capable of being used for all the purposes to which this fine metal may be parti-

particularly applied. It is in this manner it is still wrought in Paris, somewhat in the large way: that it is fused and moulded at first into thick plates, of the form of a parallelogram, which are afterward heated red-hot, and drawn out into bars or flat ingots, by repeated hammering. By means of these repeated strokes on the platina alloyed with arsenic, which is brought to a red heat before it is beaten, the arsenic is separated and volatilized; the metal refines, becomes infusible, but retains its ductility, so that it can be wrought and managed like iron, which, however, is much more easy to forge. When it has been heated and strongly hammered a pretty considerable number of times, it is found to be pure, and no longer contains any arsenic that is perceptible. Notwithstanding every artist at Paris, who manufactures this metal at all in the large way, is supposed to use a peculiar process, it appears, that what I have here related is generally followed, because arsenic alone possesses the double and important property of promoting the fusion of platina, and of quitting it more or less completely by the action of caloric long continued, and the hammering employed to forge it.

26. We know nothing of the combinations of platina with tungsten, molybdena, chrome, titanium, uranium, and manganese. We have had too few of these different metals pure, as well as too little of platina itself, and have expected too little from its union with these metallic substances

stances, for us yet to have examined the attractions that exist between them, as well as the products of their union. The same may be said of cobalt and nickel. Bergman, comparing together the properties of these last metals, has shown that they have a considerable analogy to each other, and at the same time to iron: and he has expressed a doubt, whether they were not all, and in particular platina, to be considered as modifications of iron, or rather as various states of one and the same primitive metallic substance, capable of assuming a number of different forms and qualities, according to the various circumstances in which it is placed by nature or treated by art. But with his usual precision and clearness of reasoning he has concluded, from all the facts which he has collected on these different metals, that platina, which has never been separated into different substances, and the nature of which has never been imitated by any mixture whatever, was really a distinct metal.

27. Bismuth unites very well with platina by fusion; and the result is a metal so much the more fusible and brittle in proportion as the bismuth is in larger quantity. This mixture easily changes its colour in the air, in which it becomes yellow, purple, and blackish. It cannot be purified by cupellation: and when the proportion of bismuth diminishes, the platina, resuming its infusibility and natural in-

tractable character, fixes in a swollen mass, porous and scoriiform, which still retains much bismuth, and remains extremely short and brittle. It must be observed, however, that these phenomena have been seen and described only as occurring with impure and crude platina; and that no attempt has been made, to examine this mixture with the purified platina of which I have spoken above.

28. It is known likewise, that crude platina easily fuses with antimony; and that the result is a metal with facets, very brittle, from which antimony may be separated by the action of fire, but which retains the last portions with such obstinacy, as to lose much of its specific gravity and ductility. It is with this combination, however, as with the preceding; the mixture of pure platina with antimony has not yet been examined, and we know not the properties of this compound, which requires further research. The same may be said of the sulphuret of antimony, which the alchemists so frequently employed to purify gold, and which, from analogy, may have the same action on crude or impure platina; but no attempt has yet been made, to employ it for this purpose.

29. Almost all chemists, hitherto, have agreed in saying, that mercury cannot unite with platina, and that we cannot make an amalgam with this metal. Besides, there was some reason for adopting this opinion, as it was known
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that in America gold was separated from platina by means of quick-silver; and that the platina was not obtained, till the ore containing both the metals had been triturated with mercury. However, on a careful examination of the properties of crude platina, a portion of quick-silver is pretty frequently found in it. Scheffer and Lewis endeavoured in vain, even by the help of water and the nitro-muriatic acid, to amalgamate platina. Citizen Guyton having found that the adhesion of a plate of platina to quick-silver was much stronger than that of the metals incapable of an union with it, and that it came pretty near the adhesion of some which dissolve in it without much difficulty; and that it even exceeded the adhesion of zinc and antimony, which may be combined with it; he attempted to effect this union, and succeeded to a certain point, by a process different from what had been before practised. A very thin plate of pure platina, being placed and confined under mercury, at the bottom of a matrafs, in a sand-bath, heated so as to keep the mercury boiling fast, and to bring the matrafs to a strong red heat, came out of the metallic fluid with an increase of weight, penetrated with mercury, and very brittle; in short, in a very decided state of amalgamation. This kind of combination, indeed, sensibly differs from that of metals truly soluble in quick-silver, since the platina does

not lose its solid form, and does not dissolve; but it is at least much more sensible than that of iron, to which platina had been compared with regard to insolubility in mercury. It is easy to see, that on account of this difficulty of solution, mixtures of some very soluble metals of platina may be treated with mercury, which would separate the former, without touching the pure platina.

30. Zinc easily combines with platina, and renders it very fusible. The compound arising from it is brittle and hard to file; and has a tinge of blue, particularly when the platina is in greater quantity than the zinc. By heating this mixture a long time the zinc is separated, volatilizing and burning in its surface; but the last portions of zinc, like those of bismuth and antimony, in the mixtures with these metals, are very difficult to separate.

31. Platina very easily unites with tin. This mixture is one of the most fusible, and one of the most easy to melt and cast. Unfortunately it is very brittle, and easily broken by a blow, when in the proportion of equal parts of the two metals. Twelve parts of tin to one of platina, form a very ductile compound, but of a rough and coarse grain, which grows yellow in the air. Hence we see, that platina appears greatly to diminish the ductility of tin: it is an analogous compound, which, with the addition of copper, has been proposed
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for the fabrication of mirrors for telescopes. Lewis asserts, that he accomplished the oxidation of platina, and its solution in muriatic acid, by means of its union with tin. We know, in general, that metals, in their reciprocal combinations, acquire combustibility.

32. Platina fuses very well with lead, but not without a stronger fire, than is required in the preceding case. The ductility of lead is singularly altered by its union with platina: the compound resulting from equal parts of the two metals inclines to purple; it is striated, granular in its fracture, and brittle; and is readily altered in the air. The cupellation of platina by lead has been considered by all authors, who have occupied themselves about this important metal, as one of the most interesting operations they had to try, because there was reason to expect, that it would serve to purify it, as it does gold and silver. Accordingly they attempted it a number of times, but rarely with success, on account of the infusibility of this metal. Lewis was one of the first who in vain attempted to cupel platina in common cupelling furnaces, notwithstanding the great heat employed. The oxidation, and vitrification of the lead, as well as the absorption of the glass by the cupel, take place only at the beginning, and while there is a superabundance of lead; but the platina soon fixes, the operation ceases, and the metal remains united with a portion of lead,
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so that it is destitute of ductility. Macquer and Baumé, however say, that they succeeded in completely cupelling an ounce of platina with two ounces of lead, placed in the hottest part of the furnace used for baking the hard porcelain of Sevres. The wood fire continues there fifty hours in succession. After this space of time, the platina, which they withdrew, was flattened on the cupel, and well fused; its surface was dark and wrinkled; they separated it easily; its under surface was brilliant; and it admitted very well of extension under the hammer. They satisfied themselves that this platina was very pure, and contained no more lead. Two pieces of platina thus cupelled, being brought to a white heat, and hammered one upon the other, welded together firmly. Citizen Guyton equally succeeded in cupelling a mixture of one drachm of platina and two drachms of lead by using Macquer's wind-furnace. The operation, performed at four times, took up in all twelve hours. This chemist obtained a button of platina, not adherent, very homogeneous, of a colour resembling that of tin, a little rough on its surface, weighing precisely one drachm, and not attractable by the magnet. From the results of these two experiments we see, that they furnish us with a process, capable of yielding pure platina fused in globules, malleable, and easily reducible into plates, capable of being forged, and consequently of being employed in the fabrication

brication of various utensils. But it is no less evident, that these expensive and difficult processes can never be considered as adapted to the arts, and can only be employed for some delicate operations of science.

33 Lewis fused cast iron with platina; and from these he obtained a compound so hard, that the file would not touch it. It possessed a little ductility, but it broke short when red hot, in consequence of the different fusibility of its two ingredients. The same chemist could never accomplish the union of platina with forged iron; by means of which he hoped to unite the hardness of tempered steel with the great ductility of platina. This impossibility of a union between platina and iron, militates strongly against the idea of platina entertained by some chemists, who have thought it to be either a species of iron, or a native compound of iron and gold. There is no instance of a compound metal, which does not unite with either of those that enter into its composition. It is true, that the extreme infusibility of the two metals to be united in this compound, is a great obstacle to its formation. It is obtained very easily, however, by means of a third, particularly of tin, lead, or zinc.

34. Platina fuses better with copper, to which it imparts hardness. When the proportion of copper exceeds that of platina three or four times, the compound possesses ductility; and is capable of an high polish which

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it does not lose even after it has been exposed to the air for ten years. It was with this metallic compound, to which they added arsenic to render it more fusible, that Citizens Rochon and Carrochez made very fine mirrors for telescopes, of an accurate polish, of a very fine grain, and completely unalterable by the contact of air.

35. Platina easily unites with silver by fusion, though it is difficult to cast this mixed metal. It greatly increases the hardness of silver, and renders its colour dull. If this compound be kept some time in fusion, the two metals separate. In this fusion, Lewis observed, that the silver is thrown towards the sides of the crucible with a sort of explosion. This phenomenon has since been observed with silver alone, strongly heated, by Citizen Darçet, as I have already mentioned in the history of this metal. Tillet, in the experiments he made on the mixture of these two metals, and on their separation by a kind of parting, by means of nitric acid, obtained platina separated in the crystalline form of fern leaves, and partly attacked by the acid.

36. Gold unites well with platina, though it does not melt with it without the application of a violent heat. Platina greatly changes and diminishes the colour of gold, unless it be in very small quantity. It has been observed, that this alteration of colour does not take place, unless above a seventeenth part of platina be employed; for with this or any less proportion

tion, the colour of gold is not perceptibly altered. Platina does not sensibly affect the specific gravity of gold, or its ductility; on which account it has been fraudulently used for the sophistication of this metal. The Spanish government, in consequence of the ease with which this fraud may be committed, has prevented the importation of platina into Europe, and ordered it to be thrown into the rivers as fast as it was extracted from the gold ores, among which it was diffeminated. But I have already said, and I shall soon show more at large, that chemistry furnishes analytic means, as certain as easy, of detecting the mixture of platina, and very readily estimating its proportion, by experiments as accurate, and which may become as familiar as those which constitute the art of assaying.

37. Those naturalists and chemists, who have thought with the illustrious Buffon, that platina was a native compound of gold and iron, have been led to this opinion merely from analogies, which may be considered as very ingenious indeed, but are founded on no accurate experiment. A metal resembling platina has never been obtained by any artificial mixture of gold and iron, in whatever proportion made; and neither gold nor iron has ever been extracted from platina, when well purified. To say that nature employs means unknown to us, to accomplish this sort of metallic combination,
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and to render this compound indecomposable, or impossible to be destroyed and ascertained by art, is to admit a supposition, which no established fact throughout the whole science of chemical analysis renders probable; and it is obvious, that with such suppositions we may frame a series of romances, or fictions, which would never be any thing more than fable, not natural history.

G. Action on Water and on the Oxides.

38. WHAT I have hitherto made known of the properties of platina proves, that this dense metal is too feebly attracted by oxygen, to be in any way alterable by water. There is one case however, in which it might be supposed to act on this principle of water; that in which it oxides when inflaming in a gas, which contains no other oxygen than that of the water, held in it in the state of vapour: but this water is decomposed only by the explosive electric spark; and the action takes place only at the moment when this oxygen, separated from the hydrogen, offers itself to the platina greatly heated and divided by the effect of the electricity, as I have already shown above to be the case with gold and silver. This oxidation of platina is likewise less easy, than that of these two metals.

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39. For the same reason as this metal has no action on the hydrogenous oxide of water, it has equally none on the metallic oxides. There is no one from which it takes oxygen : on the contrary most of the other metals commonly take from it this principle, and unburn it with more or less energy, promptness, and facility.

H. *Action on Acids.*

40. PLATINA is one of the metals that act least on acids, and are the least soluble in them. The most concentrated sulphuric acid, assisted by the most powerful heat, does not attack it in any manner, or experience from it the least alteration. It is the same with the nitric acid : and though the nitrous acid appears capable of attacking it slightly, as it does gold, it acts much less sensibly than on the latter metal : accordingly all chemists have unanimously asserted, that platina is not soluble in the acid of nitre. The strongest muriatic acid has no action on platina, even when assisted by long ebullition : this perfect want of action on platina, and its powerful action on iron, enable us to employ the muriatic acid for separating iron from platina, and purifying the latter metal. Distillation, such a powerful mean of oxidizing and dissolving most other metals, in no respect promotes the alteration of platina by acids : and it may be said, that of all metallic

tallic substances this is the only one, which experiences no alteration from almost any acid. Thus the phosphoric, fluoric, boracic, carbonic, and the four metallic acids, much more feeble than the first three of these, have absolutely no effect on pure platina in its metallic state: the acids furcharged with oxygen alone, and which adhere feebly to this principle in excess, are capable of dissolving it, as will presently appear.

41. Three acids alone, or the muriatic acid in its triple circumstances of super-oxygenation, oxide and dissolve platina. The fluid oxygenated muriatic acid acts quickly on this metal, and at a heat of 15 or 20 of Reaumur's thermometer. The oxidation and solution of platina take place without any sensible effervescence, because it takes up silently as it were the oxygen adhering feebly to the muriatic acid, without being obliged to separate it from any base, capable of assuming the form of gas; a circumstance which, as I have already mentioned several times in the preceding articles, is the sole cause of the effervescence, that accompanies so many other solutions. In proportion as the platina is thus quietly oxidized, it is dissolved in the same manner by the muriatic acid left dis-oxygenated, the attraction of which for the oxide of this metal is as strong, as its attraction for the metal itself is feeble. The solution produced in this case is but very weak, and contains

contains very little of the oxide, on account of the very small quantity of muriatic acid remaining in the water, as this fluid contains no great portion of the oxygenated muriatic acid at first. Accordingly this solution of muriate of platina, which would have been of a brown-red colour if saturated, is but of a deep yellow, or light orange. It resembles the two following however in all the properties it displays, they being only weaker and less striking, in consequence of the small quantity of oxide of platina it contains.

42. The muriatic acid loaded with nitrous gas, and still more the muriatic acid mixed with nitrous acid, as it is in the state in which it was formerly called *aqua regia*, acts much more powerfully and rapidly than the oxygenated muriatic acid on platina. Here, as in the solution of gold by the same re-agent, it is the nitrous oxide, which, assisted by the strong attraction of the muriatic acid for the oxide of platina, is decomposed, yields its oxygen to the metal, and renders it soluble in this acid. It has been observed, that the nitro-muriatic acid most proper for this solution, and which succeeds best for it, is that which results from the mixture and re-action of equal parts of nitric acid and muriatic acid. This action, however, is much less easy and less distinct, than that which the same mixed acid exerts on gold;
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which is owing both to the extreme density of platina, which is nearly one fourth greater than that of gold, and to its much more feeble attraction for oxygen. Accordingly, to succeed in this solution we are obliged to have recourse to a process, which is not requisite for accomplishing that of gold. Into a glass retort is put one part of pure platina in fine filings; or grains of platina well separated from sand, iron, and gold, from the first by washing, from the second by muriatic acid, and from the third by accurately picking it grain by grain: on this are poured sixteen parts of nitro-muriatic acid, made with equal proportions: the retort is placed on a sand-heat, and a receiver is adapted to it: and the acid is boiled, as if it were to be distilled. At first a little nitrous gas is evolved; then real azote gas is produced, apparently by the complete decomposition of the nitrous oxide or gas. This gas is separated but very slowly, and in no great abundance, because the platina absorbs but little oxygen, and requires probably not more than 5 or 7 per cent. for dissolving in muriatic acid. The solvent assumes a yellow colour, which changes to orange, then to a deep red, and at length to a dusty brown.

43. This muriatic solution of platina, one of the highest coloured metallic solutions known, is of great acrimony, or absolutely caustic. It corrodes and burns animal substances: the discoloration

coloration it produces on the skin becomes of a blackish brown, and never assumes that fine purple tint, which distinguishes the solution of gold in the same acid. It has been remarked, that when very pure platina is separated from all the iron which it contains in its ordinary state, it never takes any colour but a deep orange yellow, and hence the deep brown of the common solution is attributed to the iron it contains. It is true, that most of the solutions mentioned by chemists have been made with crude and very ferruginous platina: however, on diluting the deep brown solution with water, it becomes first of an orange colour, and then of a bright yellow, which approaches that of the solution of gold. Frequently, when this solution is very thick, it deposits on cooling little amorphous crystals, nearly pulverulent, of a fawn colour, which are true muriate of platina. Macquer says, that by evaporating this solution of platina gently, and afterwards letting it cool, much larger and better defined crystals will be produced, than those it yields spontaneously after saturation. Lewis having left the same solution to evaporate spontaneously in the air, obtained from it deep red crystals, pretty large, irregular, and resembling the sublimed benzoic acid, only a little thicker. Bergman asserts, that it yields on evaporation crystals of a brown red, frequently opaque, sometimes transparent, very small, irregular, in
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angular grains, the true figure of which he found it impossible to determine. These crystals, washed and dried, are less soluble by ebullition than sulphate of lime itself: their solution is yellow, and deposits a little pale flocculent precipitate, which Bergman supposes to be oxide of iron. Thus we find much disagreement in authors respecting the muriate of platina; which proves, that they operated on the impure metal, and that they did not all treat it in the same manner, or by the same process of dissolution.

44. The muriate of platina is of a rough and astringent taste. Without being caustic like that of gold, it is decomposable by fire, lets its acid exhale, and yields a grey oxide. The concentrated sulphuric acid occasions in it a precipitate. Pot-ash first produces in the solution small red crystals, frequently octahedral, which are a triple salt: an excess of this alkali forms in it a precipitate of yellow oxide: the sulphate of pot-ash produces the same triple salt. Though Margraff has asserted, that soda does not precipitate the muriate of platina, Bergman has obtained this precipitation by employing a larger proportion of the alkali. The oxide thus thrown down is yellow, and as it were spongy: no crystallized triple salt is formed here as with pot-ash. Ammonia likewise produces crystals of a red or yellow triple salt, of an octahedral figure, which is ammoniated muriate of platina.

tina. Soda decomposes these crystals, and separates from them a coloured oxide: pot-ash does not separate the same oxide, but takes the place of the ammonia, forming a triple muriate of pot-ash and platina. The ammoniacal salts, and particularly the muriate of ammonia, precipitate in like manner the muriate of platina in a yellow triple salt, granular, and little soluble. The same salt is obtained by pouring a solution of muriate of ammonia into the salt of platina formed with the oxide of this metal, obtained by means of soda, and dissolved in the sulphuric or nitric acid. Thus it is a common property of the salts of platina, according to the experiments of Bergman, to form with pot-ash and ammonia, or with the salts of these bases, triple salts, that are little soluble, crystallizable, and decomposed by the action of heat and slow digestion with soda. Lime acts precisely like soda on the muriatic solution of platina: it precipitates from it an oxide, and does not form a triple salt. On this occasion Bergman brings together by an ingenious comparison soda and lime, pot-ash and ammonia; remarking that the latter two, as well as their neutral salts, occasion the crystallization of alum, while neither soda nor lime, nor their neutral salts, produce the same effect. In the same place in his dissertation on platina he observes, that alum ores naturally contain pot-ash, or that pot-ash is formed during their

calcination, so that then it does not require to be added in manufacturing this salt. Thus by this general view, to which he was led by an examination of the solution of platina, he has foreseen as it were with the eye of genius the discovery, that Mr. Klaproth and Citizen Vauquelin have made of the presence of pot-ash in stones.

45. The precipitates or triple salts obtained by pot-ash, ammonia, and their salts, added to the muriatic solution of platina, have the important property of being reducible without addition, in a strong fire urged by bellows, into metallic globules, as de Lisle first discovered with the precipitate made by the muriate of ammonia; and as Sickingen has since confirmed, by making the experiment on a much larger scale. Bergman, who generalized this property, by finding it likewise in the precipitates made by pure ammonia, pot-ash, and the salts of pot-ash, observes, that they fuse well before the blow-pipe by the help of the triple phosphate of urine, which retains the powder. He thus obtained a very small brilliant grain, which he flattened upon an anvil into a plate of about a line in diameter. Seven or eight such little plates were united well together by the same process, but into a single globule, which Bergman compares for size to the head of a common pin. These retained their ductility; but he was not able to fuse greater quantities so perfectly,

fectly, as to prevent their breaking under the hammer. The crystallized muriate of platina, and the precipitates of this metal which are not saline, did not display to him the same quality of being reducible; whence he infers, that ammonia and pot-ash influence the fusibility of these oxides in some peculiar manner. At present we see the singular agreement existing between this fact observed and described by Bergman in 1777, and the art of fusing and working platina in the large way published by Jeannety in 1790. Sickingen's process consists in first purifying platina by amalgamation; dissolving it in nitro-muriatic acid; separating the iron by means of prussiate of pot-ash, which precipitates this metal, while the platina still remains dissolved; precipitating the platina with muriate of ammonia; afterward exposing this precipitate to a strong fire, and adding the art of forging to that of fusing it: by which process he has obtained from crude platina five eighths of pure platina, capable of being forged when heated, and sufficiently ductile to admit of being flattened and drawn into wire. This process, however accurate and valuable it may be to the chemist, is manifestly too expensive to be adopted in the large way: but it will be seen below, that for the fabrication of certain chemical utensils it is preferable to that performed with pot-ash and arsenious acid, because this

does not always answer every condition required in the fabrication of these utensils.

46. Bergman, after having described with much care the process, in which he obtained very small globules of platina by fusing the ammoniacal precipitate with triple phosphate, observes that this metal, deprived by this operation of all the iron it contained, exhibited properties very different from those of crude platina. In fact, these globules had a very bright silver colour. The most powerful magnet did not attract them, and they had no magnetic property. No acid, except the oxygenated muriatic, attacked them. The nitro-muriatic acid, composed of equal parts, dissolved them, assuming first a yellow colour, which at length became red. This solution yielded on evaporation, granular crystals of no determinable form: it exhibited the phenomena of precipitation and of triple salts mentioned above. The prussiate of pot-ash did not precipitate it, but merely heightened its colour, because it formed a triple salt. This last fact proves, that the platina contained no iron; since on adding sulphate of iron to this solution, in the proportion of $\frac{1}{1000}$ part of the platina it contained, a blue precipitate was formed, though the iron in it then was only $\frac{2}{100000}$.

47. The oxide of platina, precipitated from its solution by lime and soda, is reduced to platina by a strong fire, assisted by some fluxes,
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particularly borax, tartar, and a fusible glass. Macquer thus fused it in thirty-five minutes, in a forge fire urged by two powerful pairs of bellows, into a button which was not ductile, and which was hollow within: its texture was granular, and its fracture coarse: its hardness was similar to that of forged iron; it scratched gold, copper, and even iron. A precipitate formed by pot-ash, and which was a triple salt, exposed to the focus of a burning-glass, gave out a thick vapour of muriatic acid, and fused into a smooth button, brilliant, vitrified, and brittle. The true precipitate by alkali is soluble in the simple acids, but much more easily in the nitro-muriatic.

48. According to the first assays of Margraff and Lewis, the nitro-muriatic solution of platina is precipitated by the metals, and particularly by tin, into a reddish oxide. The same effect takes place with the solutions of most of these metals. From a comparison of their experiments it appears, that the solutions of bismuth and lead by the nitric acid, of iron and copper by different acids, and of gold by the nitro-muriatic acid, produce no precipitate in the solution of platina; and that those of arseniate of pot-ash, nitrate of zinc and silver precipitate it; the first in a crystallized substance of a fine gold colour, the second in an orange-red substance, and the third in a yellow powder. It is evident, that these precipitations, like that
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of the solution of gold by the muriate of tin; are occasioned by the dissolved oxides seizing the oxygen of the platina, and precipitating themselves too much oxidized, while that of platina, being deprived of its oxygen, quits the muriatic acid.

I. Action upon the Bases and the Salts.

49. THERE is no action between the earths or the alkalis and platina. Its oxides combine very difficultly with the first by vitrification. Attempts have been made, however, to employ them in the manufacture of porcelain; and a kind of olive-grey, or brown, but of a dead and dirty hue, have been obtained from them. Lewis, and Citizen Baumé, in their assays in this way, obtained only reduced grains and ramifications, or a sort of metallic lace-work.

50. Platina experiences no alteration from the greater number of salts. The sulphates fused with platina in grains, separate from it on the surface, and acquire a reddish colour, by the help of the iron which they dissolve. But the nitrate of pot-ash, and the super-oxigenated muriate of the same base, manifestly alter and oxide it by means of fusion. Lewis first observed and described this kind of alteration. By heating for three days and three nights following, a mixture of one part of platina and two of nitre, which was projected at first into a
red-hot

red-hot crucible and exhibited no detonation; the metal acquired a red colour. Boiling water dissolved the alkali of this residuum, which carried with it a brownish powder; and the platina, separated by this washing, was found to be diminished more than one-third of its weight. The powder carried off with the water, and received on a filter, appeared to be a mixture of oxide of iron and oxide of platina. Lewis imparted to it a whitish-grey colour, by distilling it several times following with muriate of ammonia, which separated from it the oxide of iron. Margraff, on repeating the experiment of Lewis, and observing the same phenomena, has added two remarkable circumstances; the one, that the oxide of platina, united in part with the alkali of the nitre, and diluted in a certain quantity of water, assumed, on being acted upon by heat, a colour as black as pitch. These facts indicate an alteration of the platina by the nitre, extremely different from the perfect inaction of this salt on gold, and even on silver. It would be an important pursuit, to resume this experiment, and to carry it still much farther, in order to learn whether a given quantity of pure platina be capable of being completely oxidized, and in what state this oxide is, particularly with regard to the proportion of oxygen. This experiment, it must be observed, has hitherto been confirmed only with respect to platina in a crude state, and in grains.

51. The

51. The super-oxygenated muriate of pot-ash acts but very feebly on platina; Citizen Guyton, however, has succeeded in obtaining a slight oxidation of this metal by the following process. Having heated red-hot in a crucible two small thin plates of platina, weighing together full two grammes, and having projected into it in different positions eight grammes of super-oxygenated muriate of pot-ash, neither detonation nor fusion took place; the salt wholly sublimed: the plates were found to be of a duller polish: they had increased in weight some millegrammes: that which was the thinnest, and presented the largest surface, had acquired more than the other: by boiling them in a weak acid, namely distilled vinegar, they lost one, only a part of what it had gained, and the other a little more: prussiate of lime poured into this acid, rendered it instantly turbid, and formed in it a greenish white precipitate: it was with difficulty made clear by means of three successive filtrations, when the liquor assumed a bright green tinge, and left a residuum of the same colour. From this experiment Citizen Guyton concludes, that platina when heated red-hot, is oxidized on its surface by the super-oxygenated muriate of pot-ash, though this salt forms but a momentary fluid bath on the metal, and evaporates speedily.



K. Utes.

K. *Uses.*

52. IT is easy to foresee, that the most indestructible, most dense, and most infusible metal known, must be a substance that will hereafter render the greatest services to society. The Spanish government, which enjoys the exclusive privilege of the existence of platina in its possessions, cannot be long before it gives this valuable metal to trade, to the arts, and, above all, to the sciences, which claim it; now that very accurate chemical experiments have taught us, that gold sophisticated with platina, can soon be detected, and even assayed with precision, by the addition of muriate of ammonia to its solution, which would render it turbid; as even platina would be, if alloyed with gold, supposing the acknowledged merits of the former should render it more highly valued, by mixing sulphate of iron with its solution, which would precipitate the gold without affecting the platina. The weight of each of these precipitates would indicate the respective quantities of the metals.

53. Some trinkets, and utensils for the table, have already been made of platina; but though they have the advantage of being unalterable and infusible, they have the real defect of not possessing a fine colour, and are at the same time very ponderous. Platina, therefore,

can be employed only for small and slender instruments, capable of being exposed to several corrosive matters, and to the air, without being altered by them; but this use is confined within narrow bounds.

54. Unquestionably it is in the fabrication of chemical vessels, that it would be most directly useful: crucibles, evaporating dishes, small retorts, and alembics of pure platina, would be of very great advantage for chemical operations; but to derive from them all the benefits that may be expected, they should be made of platina fused, and purified with phosphorus; or extracted from its muriatic solution, precipitated by the muriate of ammonia. I must indeed observe, that platina fused and purified in the large way, with arsenic, and forged, has not the degree of purity requisite for chemical operations; and that all the crucibles I have seen fabricated of it constantly become full of holes and perforated, by the fusions with saline fluxes made in them.

55. The greatest, most important, and most solemn use, that has yet been made of platina, has been within these few years, in the series of operations undertaken for determining the new weights and measures of the French Republic. The Committee of the Academy of Sciences have employed it for measuring the bases of the triangles, on account of its little dilatation and change by caloric, and of the regularity of this

this dilatation. Of it have been made the rod and weight of the pendulum, designed for measuring the oscillations at a given latitude. It will form the standard of weights and measures, which will be the perpetual and immutable types of all instruments of mensuration. Small weights will be fabricated of wires or leaves of this unalterable metal. It will be very convenient and very useful, for the construction of metallic thermometers.

56. By mixing it with copper and arsenic, in various proportions, mirrors for telescopes have been fabricated of it, which will never experience any alteration in their polish; and which unite with a bright and perfectly uniform polish of surface, a complete incapability of being altered by any possible agent.

57. Platina also promises the greatest and most important advantages in mechanics, and particularly in the delicate art of making time-pieces. The construction of a great number of machines will gain by the acquisition of this metal, which may be substituted in numerous cases for copper, iron, and even silver.

There is one art in particular of great importance, already created in France, and which to render it flourishing, requires only a sufficiency of this metal, hitherto and still an object of fraud and contraband trade. This is the art of applying its leaves or sheets to iron and copper, a species of plating far superior to that with silver for durability.

bility and unchangeableness. It is impossible to limit the immense uses to which such a plating may be applied. Culinary utensils, those of pharmacy, and even those of some manufactories, will derive from it the greatest and most frequent advantages.

58. In a word, its weight, the difficulty of combining it with any other metal without altering it, its ductility, added to a considerable tenacity, which may be increased still more by the addition of other metals, may likewise occasion platina to be employed at some future time in coins or medals.



END OF THE SIXTH VOLUME.

